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AUTHOR	Butzow, John W.; And Others
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ABSTRACT

Designed to introduce middle and junior high school teachers and students to aquaculture and sea farming, the information and lessons in this unit focus on the biology, economics, and gastronomics of these fresh and salt water activities. An extensive section containing teacher background information describes how to farm shellfish and finfish, summarizes major developments in aquaculture in the northern New England area, and discusses specific shellfish and other species. Five multidisciplinary activities focus on mussels, crayfish, and aquaculture equipment. The unit concludes with a simulation game about the oyster culture industry. Lists of organizational and commercial resources are provided as well as bibliographies of technical materials, general books, and cook books. Illustrations and student worksheets are included. (DC)

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Is Our Food Future in the Sea?

A Marine Education Infusion Unit on Aquaculture and Sea Farming

Northern New England Marine Education Project

The objective of NNEMEP is to encourage and support marine education among the teachers of Northern New England so that their students will appreciate the importance of water in their lives and in the life of the planet. The project has received support from the College of Education of the University of Maine at Orono, the National Science Foundation, and the Maine-New Hampshire Sea Grant Program.

206 Shibles Hall
College of Education
University of Maine
Orono, Maine 04469
207/581-7027

Units Revision Team

John W. Butzow, Project Director
Peter Corcoran, Curriculum Writer and Assistant Director
Susan White, Educational Materials Design and Production
Edward Hodgdon, Aquaculture Consultant
Rick Hardman, Illustration

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Contributors

NNEMEP Staff

Project Director: John Butzow 1975-82
Project Assistant Directors:
- Richard Schlenker 1976-77
- Les Picker 1977-78
- Harry H. Dresser 1978-79
- Peter Corcoran 1979-82

Major Contributors:
- Randall Amero
- John Butzow
- Clayton Carkin
- Peter Cororan
- Victor DiSilvestro
- Harry H. Dresser
- John Eiseman
- Richard Glueck
- Ruth Gruninger
- Deborah Hartney
- Wesley Hedlund
- Edward Hodgdon
- Mildred Jones
- Win Kelley
- Steven Kilfoyle
- Daniel Lancor
- Jean MacConnell
- Julie Steed Mawson
- Les Picker
- Robert Pratt
- Gail Shelton
- Lorraine Stubbs

Staff Assistants:
- Julie Brown
- Deborah Hartney
- Heidi Richards
- Michael Shirley

Developmental Art Work:
- Peter Archambault
- Lori Dombek
- Carol Nichols
- Harry Dresser
- William Hepburn
- Melanie Hodgdon

Developmental Photography:
- Les Picker
- John Butzow
- Clarence Barber

Manuscript Preparation
- Mary Blanchette Brown

Revised Marine Education Infusion Units for Middle School-Junior High School

Have You Been to the Shore Before? A Marine Education Infusion Unit on Seashore and Aquarium Life

What Adventures Can You Have in Wetlands, Lakes, Ponds and Puddles? A Marine Education Infusion Unit on Wet Environments

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Is Our Food Future in the Sea? A Marine Education Infusion Unit on Aquaculture and Sea Farming

How Do People Use Lighthouses and Navigational Charts? A Marine Education Infusion Unit

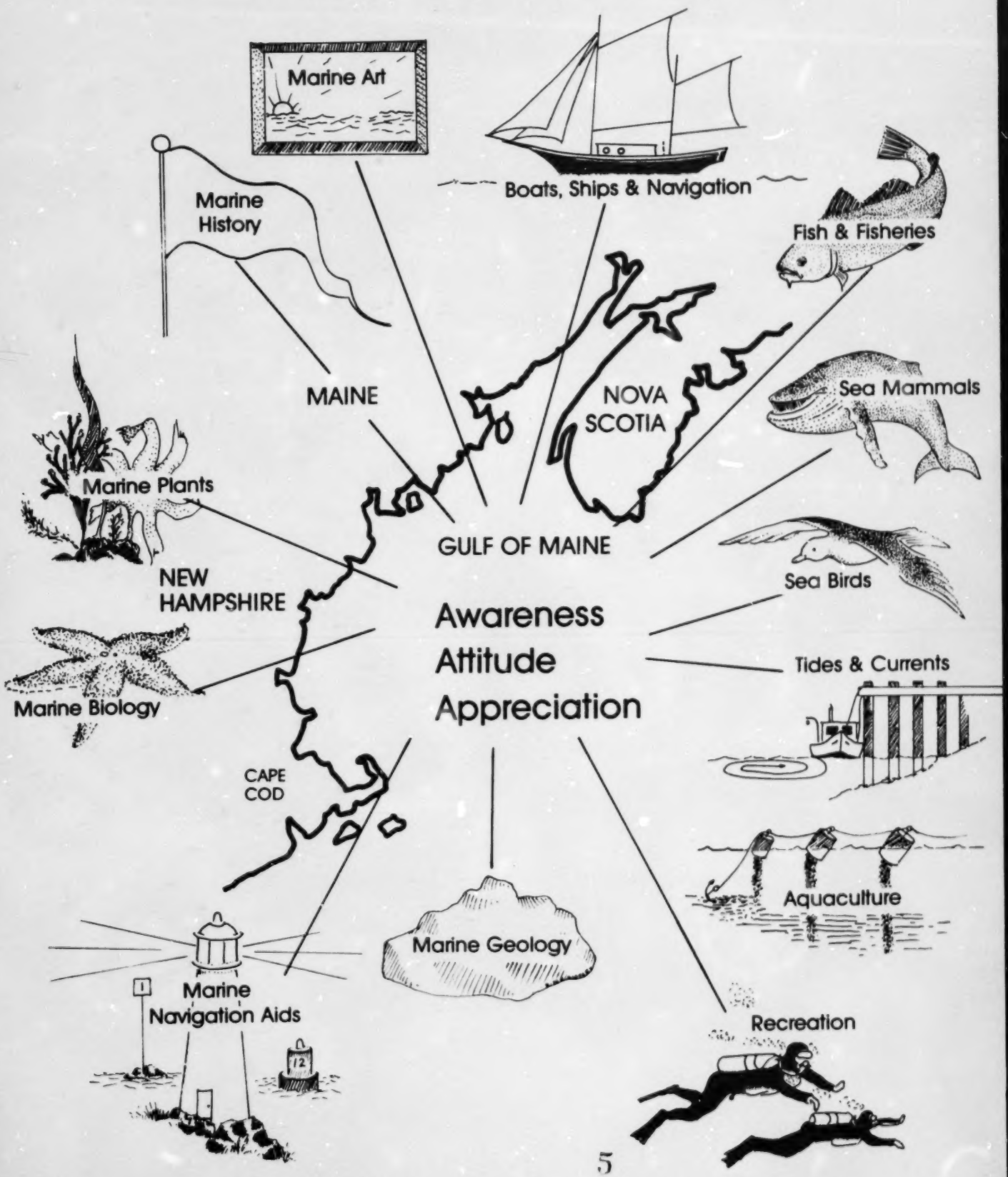
Original — Trial Editions (For Grades K-12)

Clams and Other Critters
Marine Art
The Aquarium
The Beaver
The Lobster
Whale Multi-disciplinary Studies
Our Heritage of Ships
Shipping, Ships and Waterways
The ABC's of Celebrating Year of the Coast in Your School
Have You Ever Been to the Shore Before?
Blue Mussel
Lighthouses
Wetlands
Seaweeds
Aquaculture
Navigation

More than one hundred teachers and members of past NSF sponsored summer institutes have trial tested and critiqued these units.

Marine Education

Ocean & Coast Conceptual Scheme



Foreword

Marine education is a relatively new term embracing a multi-disciplinary approach to learning about the marine environment: how it relates to people and how people change and relate to it. These units are intended to serve as points of departure for teachers and students who desire to increase their awareness of the watery world of this blue planet. Each unit includes ideas and activities drawn from a variety of content areas so that teachers of many different subjects at the junior high and middle school levels can make use of them. These units may be used in their entirety or used as idea or activity sources to infuse into the usual curriculum.

Our objective is to help teachers make learning more water-related. We did not plan a structural sequence of topics for grades five through nine, but rather offer these teachers guides and student pages for your consideration.

The general focus within these units is the Gulf of Maine. As the Gulf extends from Cape Cod to Nova Scotia it washes an extremely long and varied coast. We have dredged and seined themes from the activities, concerns, organisms, vessels, and the past of this vast watery region of North America. We aim to be inclusive rather than exclusive, suggestive rather than factual, and stimulating rather than expert. Our hope is that your students will become more questioning, interested, and critical of watery concerns. We hope your use of these materials will add water back into our culture.

John W. Butzow

A Note on Measures and Genders

Wherever practical, metric measures are used in this unit. Teachers are urged to use metric measures descriptively as well as in student measurement and observational activity.

A number of occupational words have as yet no generally used non-sexist equivalent. We have therefore retained use of the terms fisherman and lobsterman for either sex.

Contents Of The Teacher's Guide

Teacher Background Information

How Shellfish Are Farmed 1
Major Developments in Our Region's Aquaculture 5
The Blue Mussel 8
The Oyster 10
Finfish Farming 11
The Lobster 13
Algae Culture 16
Other Aquaculture Species 16

Classroom Activities

Mussel Dissection 17
Water and Nutrient Passage in Mussels 20
Eating Mussels 20
Crustacean Study 21
Aquaculture Equipment 23
The World Oyster Company Game 23

Teacher Resources

Organizational Resources 27
Commercial Aquaculture Companies 28
Laboratory Supply Houses 29
Technical Bibliography 29
Annotated Bibliography 30
A Bibliography of Cookbooks 31

Contents Of The Pocket

Mussel Dissection Figures

1. Mussel exterior
2. Mussel with Attached Drill
3. Mussel Showing Valve Orientation
4. Mussel Oriented for Dissection
5. Closed Valves
6. Open Valves
7. Mussel with Valve Lifted
8. Mussel Interior
9. Mussel Cross-section
10. Gill Detail
11. Mussel with Valve and Gill Removed
12. Mussel Intestinal Tract

Unlabeled Lobster Diagram
Oyster Stock Form
Bank Balance Form

Teacher Background Information

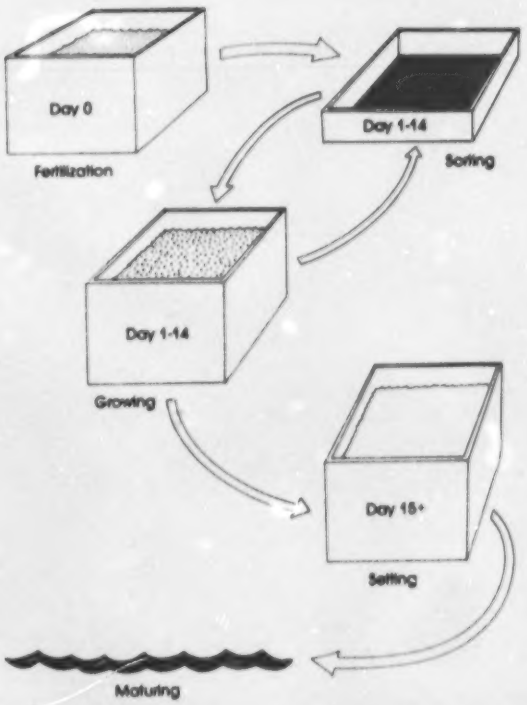
The broad purpose of marine education is to develop a marine literate citizenry; that is to educate our students about the fundamental importance of the connections of human culture to the marine and aquatic environment. The general purpose of the marine education infusion units in this series is to provide teaching materials to make this broad purpose possible for middle and junior high school teachers in Northern New England. This unit on aquaculture and sea farming seeks to introduce this promising area to teachers and students of our region. The term aquaculture is being used to include both fresh and salt water activities. This unit focuses on the biology, economics, and gastronomics of sea farming, especially of shellfish.

This unit is not a step-by-step piece of curriculum; it is designed to allow flexibility on your part. It will be necessary for you to adapt the material to your students' abilities and needs, your access to materials, and the availability of transportation for field trips.

How Shellfish Are Farmed

To provide an understanding of what an aquaculture facility is and how it operates, this section will describe the processes involved in producing a marketable organism, using the European oyster *(Ostrea edulis)* as a model. Much of what follows applies almost directly to other shellfish species such as clams, scallops, mussels, and even to finfish. The materials and techniques used in these diverse industries might appear different at first glance, but the general procedures underlying them all are similar.

Everything starts out in the hatchery. It is there that adult animals are brought together in an environment which favors reproduction. This takes the form of temperature and nutrient conditioning in the case of the oyster. After a suitable conditioning period, the animals release their eggs and sperm into the water. Since they are confined in small areas their eggs and sperm can be collected and mixed in the proper proportion to assure maximal fertilization. Once fertilized, the zygotes are transferred to a holding tank and are subsequently transferred every few days to fresh tanks, the older tanks receiving a thorough cleaning between transfers. Between each transfer process the animals are filtered to remove the larger ones; the smaller animals are discarded. The object of this process is to move the largest possible number of animals through the system in the shortest period of time under the constraints of limited space. During the first weeks of their life cycle, the oysters must be kept in heated tanks to assure maximal growth and there are only a set number of these tanks in any one facility.



Hatchery Diagram

After about one to two weeks, oysters enter the pedivelliger stage. At this point they develop an eye spot, a foot, and settle to the bottom in an attempt to set on a hard substance or substrate. Just prior to setting, the animals are transferred to heated setting tanks to provide them with an optimal setting medium. Researchers at the Darling Center in Walpole, Maine studied various types of culch materials upon which the oyster would set. It was found that shell chips are one of the best forms of substrate. The problem with whole shells or large chips was that they contained a great deal of dead weight to be processed through this system. The solution to this problem came with the adoption of what was termed culchless medium, and was nothing more than shells ground to a fine powder. The oyster is now larger than the shell chip and substrate weight is minimized.

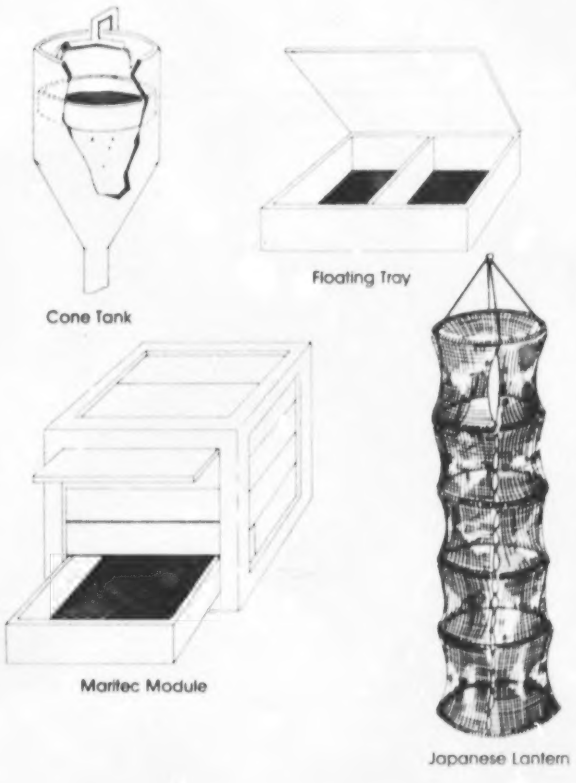
The setting process induces a metamorphosis in the animal and converts it from a free swimming to a sedentary life. Once the animal has set, it is grown on fine screening for a period of time until it attains a size that can be introduced into the marine environment with a low mortality. This depends upon factors such as the temperature, age of the oyster, and nutritional status.

Once the animals have reached a point that the hatchery manager feels they can be safely moved into an exposed marine environment, the spat, or very small oysters, are transferred into trays lined with windowscreening. The oysters will now grow at a rate determined by factors such as the quantity of planktonic or floating algae they prefer to eat, the temperature of the water, and how densely they are packed into the trays. If all things are favorable, the animals will double in volume every few days until they experience a physical crowding. During this rapid growth phase, the animals may have to be transferred to new trays very often — keeping the sea farmer very busy "weeding" the garden. This process of rapid growth and transferrence is repeated during the entire first year. It is interspersed with frequent cleaning, or defouling, and sorting to remove the largest animals to larger mesh trays. The idea behind moving the animals to the largest mesh tray on which they will stay is that the larger the mesh, the longer period of time it requires to foul. The longer the oysters can grow without labor intensive intervention, the more efficient and cost effective the operation is.

Fouling is caused by rapid growth of competing organisms such as algae and other shellfish. Trays which are not carefully and frequently cleaned or defouled will allow the animals to choke. This is because oysters, mussels, and other filter feeders "comb" out small planktonic algae from the water as food and they breathe by having passing water lose its dissolved oxygen over their gills. If water flow is impeded, reduced growth and, in the extreme, death will ensue.

Starting from microscopic size, oysters will reach a size something less than 30 to 35mm in diameter before the first winter. Much of the research that has been conducted on overwintering mortality indicates that oysters that are able to attain the 30 to 35mm size range prior to overwintering have a very good chance of surviving the stress of the winter months. This is not to say that smaller animals will die; in fact, they might prosper during the next growing season. It is quite likely that a large percentage of the mortality that a farmer experiences during the winter will occur in the 15 to 20mm size range.

Various types of containers will be used to hold the growing oysters from this point until they are sold. The only difference in treatment of small and large animals is the density of packing and the size of the mesh of the containers. There are two general kinds of devices or modules for shellfish grow out — the Japanese Lantern and the Meritec module. The Japanese Lantern is named because of its appearance. It consists of a series of double-dipped galvanized rings coated with two layers of vinyl connected by nylon mesh. The whole module costs around $30 to $35 and is both lightweight and easy to store because it collapses almost flat. The lantern is round and capable of holding 1000 to 1500 adult marketable oysters. These containers can be made nearly neutrally buoyant by tying styrofoam containers to their tops. They provide a lightweight system of growing and harvesting the



Grow Out Devices

oysters. The problems with this design are: 1) They are too fragile individually to withstand heavy loading which necessitates a large number of lanterns, 2) the rings will deform during rough handling, 3) predators such as crabs can cut the mesh, 4) getting the oysters into and out of each compartment in the lantern is time-consuming hard work, 5) washing and defouling is awkward because the animal must be taken out of the lanterns.

The second device used to house growing oysters is the Meritec module. It is named for the company which designed it. The Meritec module is nothing more than a box with drawers which pull out much like the drawers in a dresser chest. Each drawer consists of an oak frame around which mesh material is wrapped. The top drawer is covered with a flat plate of mesh in a wooden frame and the front is secured by a locking device. This system allows very rapid entry into the container, which substantially speeds up the servicing, cleaning, and defouling and sorting times. Since the drawers are interchangeable, several mesh sizes can be combined into one module reducing the total number of modules required. The problems with this design are its weight and awkwardness. Despite the fact that the unit can be made nearly neutrally buoyant with the use of flotation, once it is raised to the surface of the water it may easily weight 100 to 200 pounds. There is also a problem with corrosion of the metal staples used to fasten together the oak drawer pieces. They can disintegrate while under water and spill the animals.

Both the Meritec modules and the Japanese Lanterns require a floating work surface. This is provided by a specially-fitted raft called a service raft. The service raft is a wooden raft with excess flotation fitted with a hoist and track system that allows the module or lantern to be raised with a winch onto the deck. Many of the service rafts have a hole in the bottom to allow the raft to pass over the module and winch it through the hole. By placing the winch system on a track, the module can be maneuvered to different positions along the deck once it has been raised. This design allows one person to work on one module while another person is bringing up additional modules. Since the operation is very labor-intensive, the raft allows a number of individuals to keep busy.

There are various ways to secure the containers to the bottom. An older system called for each container to be weighted directly to the bottom by anchors. Newer design allows each of the modules to be hung from a line, called a long line, which extends between two points of land.

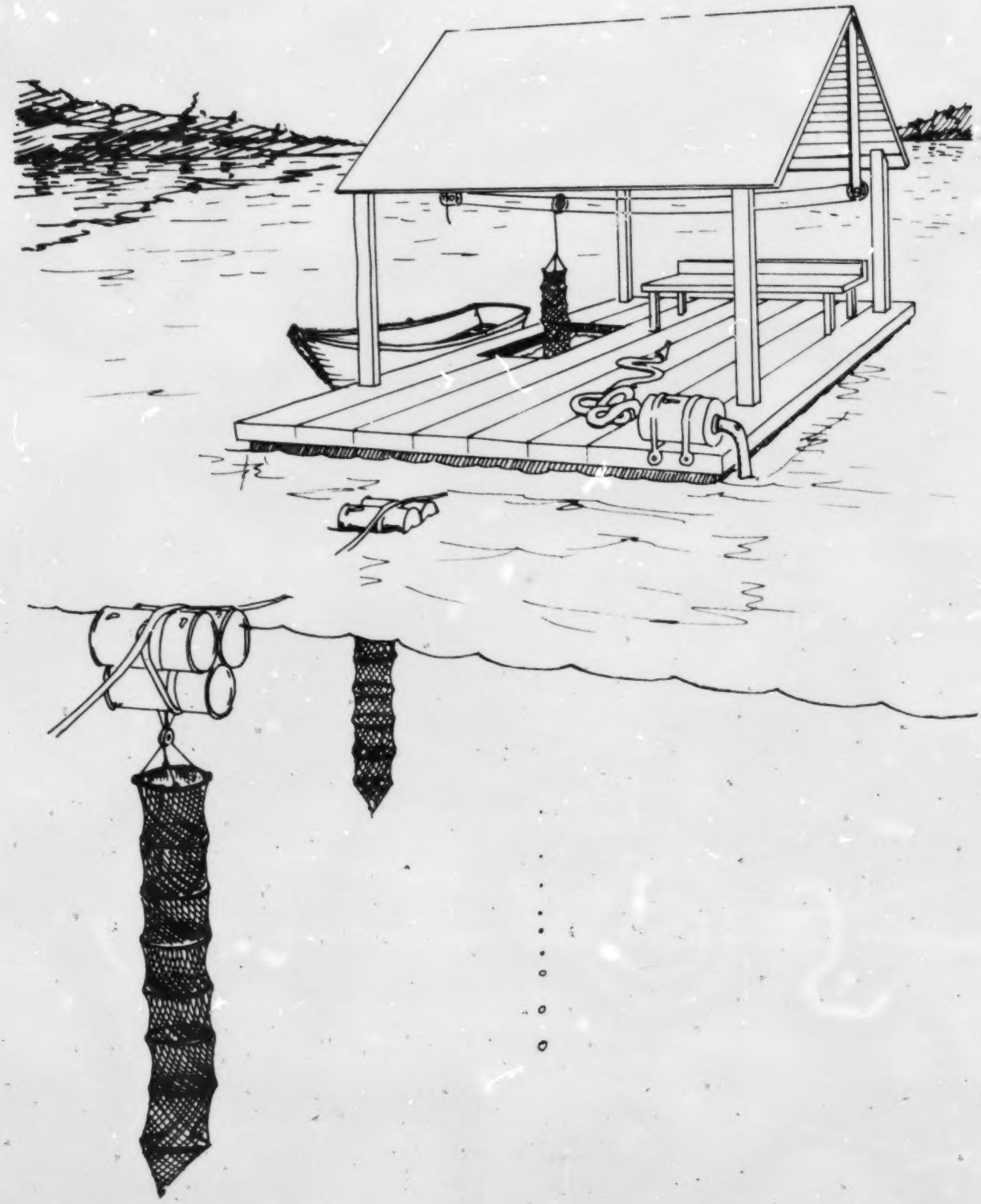
At the end of the first growing season, in late October or early November, all the oysters must be placed into a container that will allow them to overwinter. Since the animals will not grow much once they are put down, they can be packed at higher than normal densities. The module should have the largest mesh size which will hold the oysters and is buoyed off the bottom to reduce siltation mortalities. Overwintering is effected by simply sorting the animals into the appropriate size lantern or Meritec module, removing some of the flotation and/or weighing the ends and literally sinking the whole affair, lanterns and long line together.

At the end of the winter, the land end of the long line will be followed outward until the first container is encountered. This will then be raised and cleaned — ready for the second growing season. In actuality, this operation is slightly more involved. The last process is beaching the raft to protect it and allow it to be repaired. Overwintering is unnecessary if the site does not freeze over and if the winter is mild enough not to destroy equipment. If the cold temperatures, silt, and fouling do not kill the animals, if the ice does not drag the modules away, and if all the modules stay attached to the line in one piece, one can start the next growing season by simply pulling the containers up in April, May, or June.

This process must be repeated until each year class of animals (all those animals which were bought in the same size range) reaches adult marketable size — 50 to 60g, and 50 to 60mm diameter. As each oyster reaches marketable size, it is removed from the general population and held for sale. Unfortunately, the process of over-wintering and growth leading to sale is complicated by the presence of other organisms which compete with the oyster for its food and space, as well as predatory organisms which do their best to make sure that there will not be any marketable oysters. The Sea Squirt *(Bortryllus)* and the mussel are members of the first category and the oyster drill, starfish, and crab are members of the second category. Each cultured organism such as the oyster and the mussel have their own particular nemesis which seems to be each animal's particular curse. For example, mussel growers are often beset by Eider Ducks which strip the mussel lines clean. At one site, oyster growers might be up to their eyes in sea squirts and at another site infested with oyster drills.

It should be understood that one species such as mussels can often represent a major economic loss for aquaculturists growing another crop such as oysters. Because oysters grow at a slower rate than mussels, the mussel can use the oyster as a setting medium and outgrow it. This overcrowding reduces the nutrients available to the oyster and increases the fouling problems. Different growers have combated this problem in different ways. The most general procedure is to flush the undesired animals off the oysters with a stream of high pressure water.

Most aquacultural operations face a common set of problems: deterioration of equipment, over-wintering mortality, predation, diseases, and reduced yields due to adverse environmental factors. Equipment will periodically be subject to severe sea poundings and new equipment must be



Raft Picture

13

designed that will withstand this abuse while being easily serviceable and low cost. Even though aquaculture in the Northeast has not at this time branched into the field of large marine farms for harvesting algae, and seaweeds, aquaculture has already produced an effect upon our area. Acquaculture represents a means of producing quality protein at relatively low energy inputs.

Major Developments in Our Region's Aquaculture

The Maine Department of Marine Resources (DMR) was the first in our area to become involved in aquaculture. The Department has been active in experiments dealing with the cultivation of many forms of marine life since 1966. It had the first cultured oysters (*Crassostrea virginica* and *Ostrea edulis*) in Spinney Creek and later in the Marsh River in Brunswick, Maine.

Early in the 1970's the University of Maine, using state Sea Grant funds, built an aquaculture facility at the Ira C. Darling Center in Walpole. The Darling Center's program was designed to facilitate research into the feasibility of growing shellfish in the Northeast. It served as the focus around which much of the interest and expertise in the field of aquaculture coalesced. After the successful production of juvenile oysters at the center, the University became involved in a program of supplying small oysters to growers. The concept of this informal program was to gather information on the growth characteristics of the oysters grown in the Maine waters, while providing assistance and guidance to the novice aquaculturists. This program proved very successful in involved a large number of individuals in the aquacultural field.

The major problems that confronted the growers at that time were: getting enough seed, finding where to get the equipment necessary, knowing what the expected normal rate of wintering mortalities was, and determining how long would it take to produce a marketable oyster. The questions were all very basic. Few people were even aware of a second level of problems that would arise when they set about the task of producing oysters economically.

By the mid 1970's, the problem of overwintering the oysters was becoming critical. The question was not whether to move animals to a sheltered location during the winter, but where to move them. Massive mortalities during the winter of 1976-77 confirmed the fact that suitable site selection was one of the major concerns.

With each successive year, new problems will have to be met and overcome in the quest to produce a marketable oyster. Silting was a major cause of elevated mortalities in the muddy growing areas. This was rectified by growing the oysters "off the bottom." Fouling of the mesh cages by undesirable organisms was the next major problem. Frequent cleanings reduced the silting and allowed the animals to grow faster, but did not eliminate the problem.

The "floating tray" concept was developed to overcome this fouling and also to reduce the destructive forces of boring worms (*Torredo*) and encrusting barnacles. The floating tray was a container which would float partially submerged. Since the oysters were contained in the submerged half of the tray, they would receive the advantages of spending all their time in the water. The tray could be flipped so that the previously submerged half would now be exposed to the sun and air. The system seems simple in theory, especially since the temperatures and nutritive levels are both higher in the upper portions of the water column. This system promises higher yields, in shorter times, while reducing the fouling problem.

The floating tray system introduced a whole new set of problems. At the present time, many growers are using the floating trays while many others are using submerged boxes or lanterns. It seems that the only rule is "whatever works in our area is the system to use." Growing seed in surface trays, however, appears to produce elevated rates of growth.

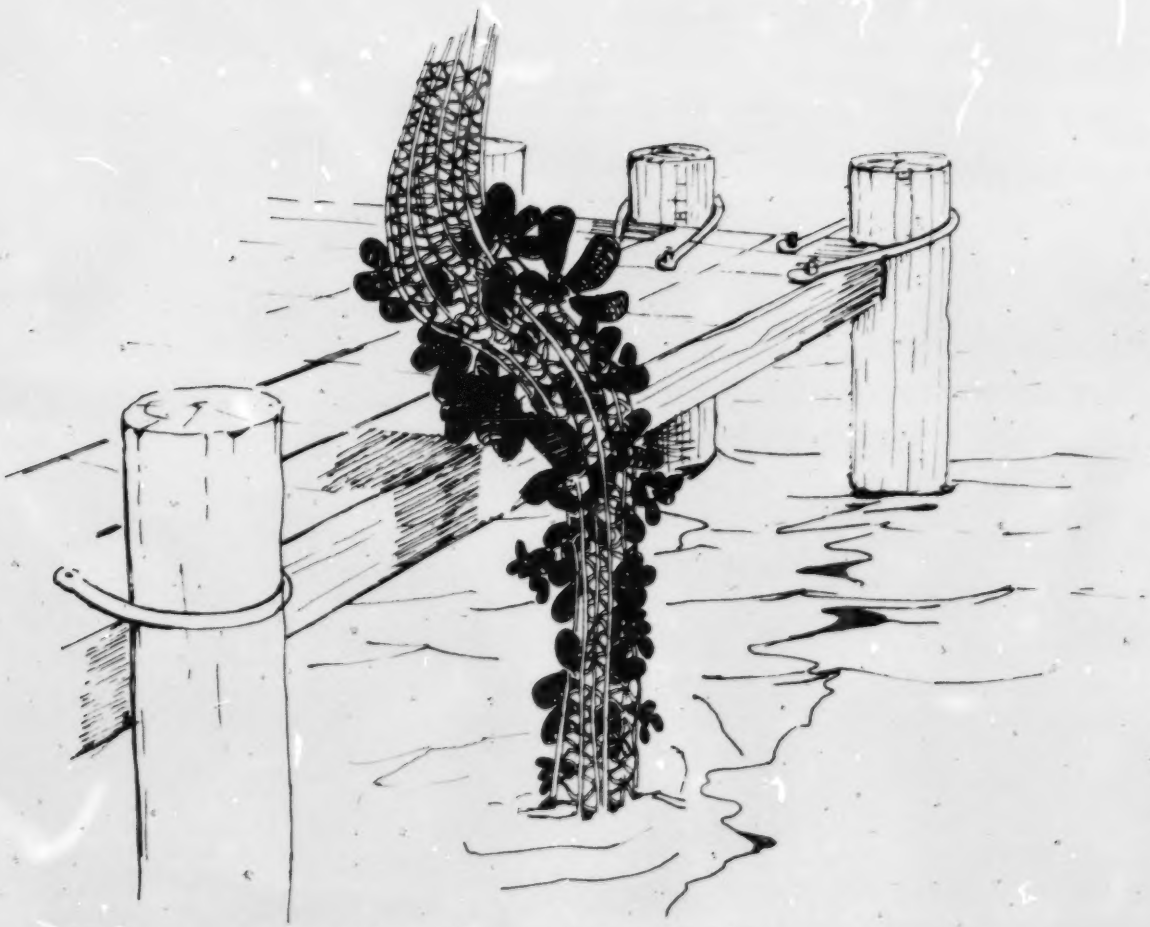
Totally submerged containers were developed simultaneously with the floating trays as a means of holding large numbers of animals in a relatively small space. These containers were suspended off the bottom by floats or runners and secured to the surface by a line. This system required the intervention of divers whenever the containers were put down for the winter and raised in the summer, but it did effectively remove the animals from the harsher surface environment during the winter months. As with the floating trays, it seems that each grower perfected a unique method of "putting animals down."

Prior to the present, most of the seed was obtained from hatcheries in California. Several local hatcheries have been started in Maine in response to the need to obtain large numbers of high quality seed. These hatcheries encountered their own unique types of problems.

The next major problems with which to contend were disease and genetically inferior seed. By 1978, many of the growers were experiencing some manifestation of the problem. This resulted in higher mortalities and longer handling times which substantially raised prices. Oysters that are less than perfect cannot be sold to the half-shell restaurant trade but must be sold at a much lower price. When the cost of handling is included, this difference could determine staying solvent. Although sea farming is an effective method of supplying a few delicacies from the sea, it is becoming increasingly apparent that only large scale, mechanized, and capitalized growers can realize a profit. The number of individuals who

grow a few mussels or a few oysters for home consumption has increased from the 1970's, but the number of aquacultural businesses has steadily declined as the pioneering aquaculturists of the early 1970's are slowly forced out of the market by large-scale growers.

In spite of there being fewer people involved in mussel culture, musselling has continued to be a major aquacultural business from its inception in the early 1970's. Mussels have certain advantages over oysters which allow them to be produced in a rafting technique. This consists of hanging an object, like a rope, from some floating device such as an old automobile tire or other float. Lines can be spaced approximately two feet apart so that the mussels will set on them. This method leaves much to chance, so a latter refinement called for "onion" bag tubes to be substituted for the ropes. The mussels are stuffed into bags and when they develop, they grow through the mesh and subsequently attach to it. This process of harvesting and repacking the mussels may be repeated several times until the mussel has reached marketable size. This type of culture method allows the animals to be grown off bottom, reducing siltation and sedimentation and provides an ample

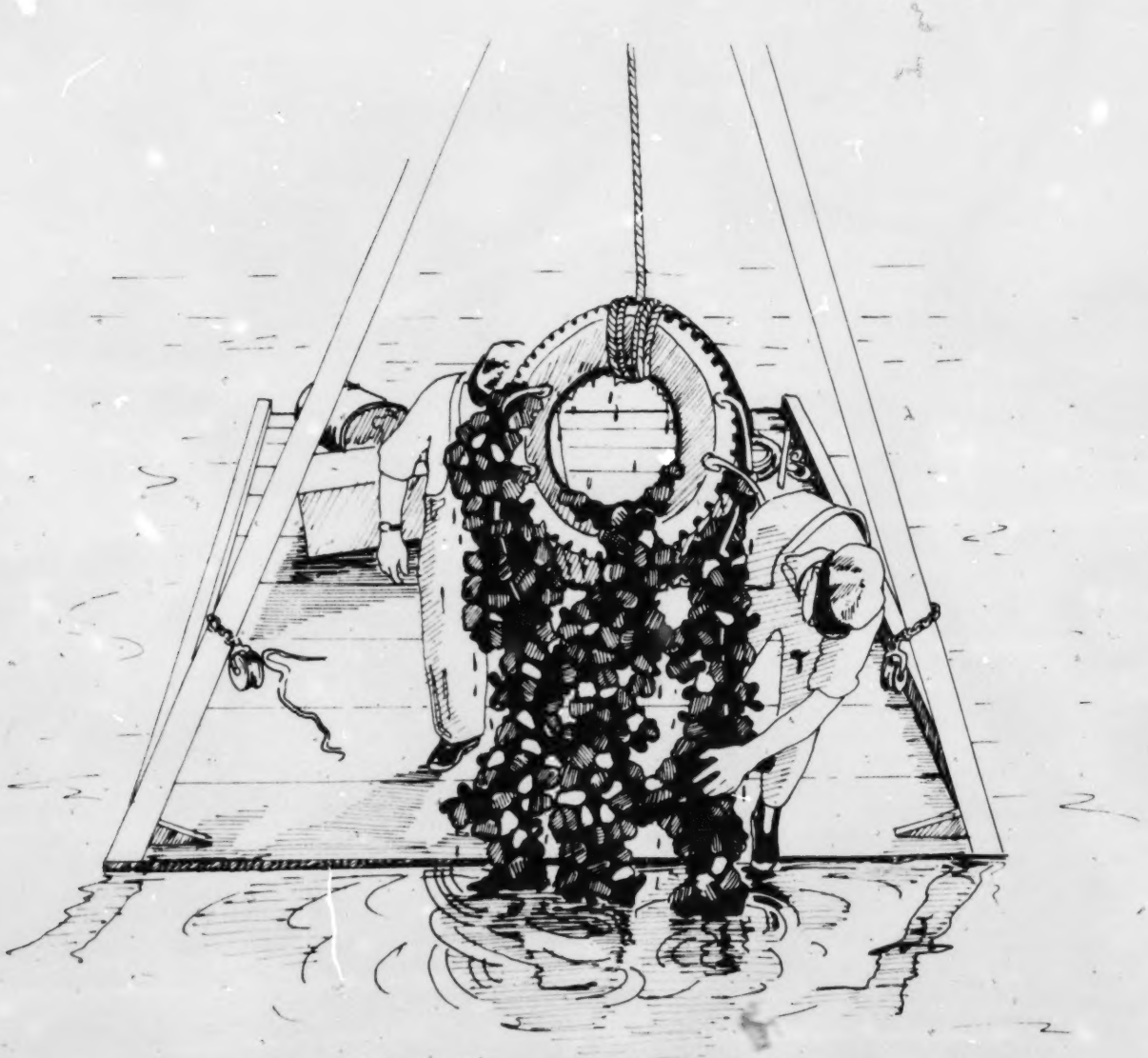


Mussel Culture by Onion Bag Suspension

supply of food by growing the organism closer to the surface. In addition, predation by snails, crabs, and starfish is reduced.

The mussel industry appears at present to have adapted itself somewhat better to mechanization than the oyster industry. Since the mussel industry has been able to overcome some of the labor intensive problems which plague the oyster industry, it appears that the major obstacle to the mussel grower is one of public acceptance of the product.

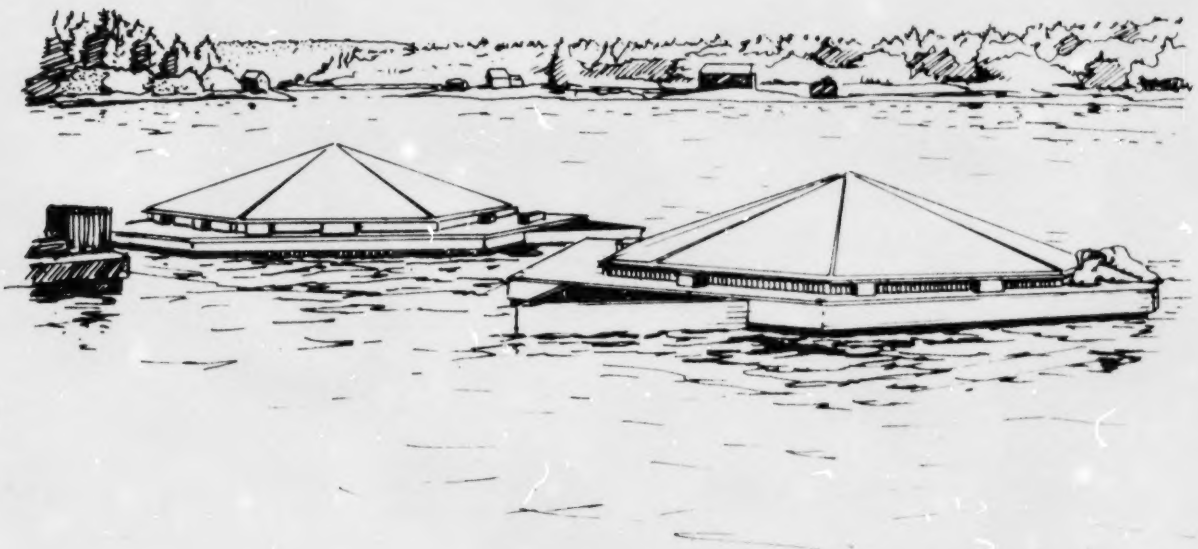
Coho salmon and steelhead trout were the first two finfish cultured in northern New England. These species were not indigenous to the area, so eggs had to be purchased from the Northwest. The first company, Maine Sea Farms, was located in Goose Pond at Cape Rosier. It was an abandoned copper and zinc mine which was converted into an aquacultural enterprise by flooding it with sea water. This farm was quite large, boasting a 40 x 50 x 60 foot growing pen which had the capacity to produce about 300,000 smolts per year. Young salmon undergo the physiological changes known as smolting when they reach a weight of approximately ten grams each. A second operation was located at the oil-fired generation station in Wiscasset and was known as the Maine Salmon Farms. Their facilities were much smaller than the



Mussel Culture by Bag-Tire Suspension

outfit at Cape Rosier being only 15 x 15 x 15, owing to the physical constriction at the growing area.

A third fishery, the Island Fisheries, was established on Vinalhaven Island, Maine. It utilized a circular pen design of fifteen foot diameter in an attempt to reduce wasted space and more nearly conform to the schooling and swim habits of the fish. This smaller unit could be covered and thus reduced losses stemming from small animals and birds. At the moment, little finfish farming is being done in our region.



Salmon Pens

The Blue Mussel

The Blue Mussel (*Mytilus edulis*) belongs to the phylum Mollusca and the class Bivalva. The blue mussel is a common inhabitant of the intertidal areas of the Northeast and even the most cursory expedition to the shore will probably reveal the location of several clumps of mussels. The mussel is so prevalent in the intertidal ecology that marine ecologists have used the locations where mussels set as a key to divide the intertidal area into zones. The reason that ecologists can do this is because the forces which influence a mussel to set in a particular area are not random but are highly specific. All marine organisms must have access to the ocean if they are to survive. They require this marine environment for several reasons: 1) to maintain their water balance 2) to reduce the drying effect of the sun 3) to facilitate oxygen and carbon dioxide transfer 4) as a food transfer medium and 5) as a means of diluting their waste products. An organism that lives its full life in the ocean has all its needs met by that environment, but an organism that spends part of its life physically removed from the water is in serious trouble from any one or all of the factors listed above. All these factors are of vital importance to our friend the mussel because it lives between tides.

Those mussels which settle just below the low water mark exist in a rather normal sea life because they are never really out of the water except during times of extremely low tides or neap tides. These mussels have only to close up their protective covers for a few hours to overcome the hardships of nature and soon they are back to the relative stability of the marine environment. What about mussels a little further up into the intertidal region? These animals are exposed to the land environment for several hours a day. In the summer they can suffer from high temperatures. What about the thermal stress if low tide occurs in the middle of the day in the dead of winter? The ambient or land temperature can easily be 30 degrees Celsius warmer or 50 degrees Celsius colder than the water environment.

The longer that an organism is out of its marine environment the greater are the stresses upon it. Higher or lower temperatures are one form of stress, but there are others. Mussels breathe by passing water over their gills. The oxygen dissolved in the water diffuses into the gills and blood and the carbon dioxide diffuses out into the water. This is exactly the same process that occurs when people breathe. In spite of the fact that we inhale air rather than water, the actual gas transfer occurs in the aquatic medium within our lungs. This is a remnant of our developmental history as marine creatures. Humans have developed the ability to breathe air while affecting a gas exchange, the mussel has not. Its alternative is not to breathe. In actuality, it respires at a slower rate and also possesses the ability to respire for a limited period without elemental oxygen at all. This slower respiratory rate or slower metabolism coupled with its system of respiring without oxygen allows the mussel to keep its shell closed in bad situations. As long as the animal is out of water and can remain closed with the water retained within the shell, this water acts to cool the animal if the outside temperature is hot and to warm it if the ambient temperature is cold. It will also reduce the drying effect of the environment and allow the animal to maintain a certain osmotic (water-salt) balance. All things being considered, the mussel has evolved a very ingeneous system which enables it to stay alive for a short period of time entirely removed from its normal marine environment.

The higher above sea level the mussel lives, the longer period of time it is out of water and the more stresses it experiences. There exists a point above which mussels cannot cope with this stress, and that point is fairly consistent for each species of mussel. This is one of the reasons why there is a mussel band in the intertidal zone. There are many other factors which influence the depth of the mussel zone other than the few that have been mentioned. For example, the zone can be extended if there are tide pools which are constantly being recharged with water. The mussel population might be virtually wiped out of an area if there were a high concentration of starfish present or some other form of predator. A colony of mussels might be easily ripped up if a storm were too severe which would in turn depend upon the frequency of storms and the degree of shelter the site provided. Along with these factors, the quality of the environment and the competition with other species must also be considered.

Mussels which are higher up in the intertidal zone do not fare all that badly when compared with their cousins lower down in the zone for, after all, they will both survive unless the environment is exceptionally severe. The biggest difference between a mussel that spends most or all of its time in water and the one that spends a fair portion of its life out of water is that whenever a mussel is out of water, it can not feed. It is the ocean which brings the animal its food. Many of the bivalves, including mussels, are filter feeders; they obtain their food by filtering water through their gills. The gills also serve the function of lungs and thus when water is passed over the gills, the animal is able to respire and eat by the same function. Since a mussel lower in the intertidal will filter feed for a longer period of time than one higher up in the zone, the first animal will grow larger and reach adulthood sooner. This differential growth rate is large. For example, a mussel grown under optimal conditions can reach market size (50mm) in less than eighteen months whereas the same mussel would require eight years to reach the same size if grown high up in the intertidal zone.

This difference in growth period is especially important to the mussel aquaculturists because mussels, like other shellfish, are subject to a parasitic infection by trematode and cestode larvae as well as acarine eggs. The mussel responds to this invasion by walling the organism off with the same material that it uses to produce new shells. Depending upon the location of the foreign body, the new shell material might be black-brown in color, consisting almost entirely of conchiolin, reddish in hue and composed of prismatic material and conchiolin, or whitish and consisting primarily of macreous material. We know these substances as mother of pearl, and we recognize the outcome of this isolation procedure as a pearl. Pearls from mussels have no commercial value but they do present a problem for the aquaculturist. The pearl can do a great deal of damage if someone bites down on it. Cultivated mussels, on the other hand, will reach market size before the pearl can become big enough to crunch in your teeth.

Mussels eat by filtering the water across the gills much like sand can be sifted through different size mesh screens. The particles that are too large remain in the water, and only the proper size particles are directed via ciliary motion towards the mouth. The rejected particles are coated with a mucous material and expelled as "pseudo feces" which contribute to the fouling problem. The higher the concentration of food organisms in the water, the faster the mussel will grow provided the food is nutritionally adequate. The end result of this feasting is a healthy, plump, little mussel ready to provide a low cost protein reserve.

The mussel filters out of the water any organisms that are the right size for consumption, regardless of the nutritional value of the organism or whether or not the food is good or bad for people. One group of planktonic organisms that are definitely bad for people is the phytoplankton which causes red tide. In the Northeast, red tide is caused by the organism *Gonyaulax tamarensis*. This organism possesses a chemical which is capable of inducing a neurological dysfunction in humans, but is harmless to the shellfish that consumes it. Because the toxin effects the nervous system and results in a partial paralysis of the victim, the disease is referred to as Paralytic Shellfish Poisoning (PSP). Since the red tide

organism responds much like other forms of plankton, there will be a dramatic increase in their numbers whenever the environmental factors are favorable. This is referred to as a bloom, and it is during these blooms that the taking of shellfish is prohibited from infected areas along the coast. The fact that mussels exhibit a rapid filtering rate makes them more dangerous during these times, because of the large number of organisms and subsequently toxin, that can be concentrated. It is possible for mussels to concentrate certain agents such as toxins, heavy metals, and other chemicals within their bodies. For example, it has been demonstrated that the mussel can increase the toxin concentration 50,000 times above ambient concentrations. This behavior is known as bioconcentration.

Life starts out for the mussel in open waters because mussels do not generally hold the fertilized eggs within shell space. In response to a variety of factors such as temperature, change in the length of the daylight, phases of the moon, and the presence of other animals, the female mussel will release between five and thirty-five million eggs into the water. The male responds by releasing milt into the water and the chance union of sperm and eggs results in the generation of a baby mussel (zygote). These young mussels are unprotected from predators in the environment and mortality rates are staggering. This is one explanation why there are so many eggs released. The fertilized egg develops rapidly, becoming a larva in a few days. The larva remains afloat for several weeks by clinging to a piece of floating debris or by trapping air between its shells. The young mussel will eventually settle to the bottom or some other suitable substrate and attach itself via adhesive threads called byssal threads. The organism does retain a foot with a sucker at its tip and so the mussel is capable of movement throughout its adult life. Most remain on the substrate to which they initially attach.

There are distinctive developmental stages through which many bivalves go as they mature. Each of these different stages presents unique problems for the organism to overcome. Most of the animals do not survive and this explains why we are not up to our ears in mussels. One could go through the calculation of a ten cm organism producing a twenty million viable offspring every year for three years to see how long it takes to cover the earth with mussels. It was the prodigeous reproductive rate of the oyster which caused philosophers to wonder why the earth was not one big oyster.

As the mussel matures it settles on a suitable substrate. The problem is that the mussel cannot settle just anywhere. It requires a complex combination of chemical and physical cues before it will send out byssal threads and become sedentary. Getting out of the water column means that it is relatively safe from certain predators. It also reduces the competitive pressures for food and space since it is entering an environment that many marine creatures cannot enter. This stationary life in a new environment possesses a whole new set of problems. Predators such as the dog whelk (*Thais lapillus*), rock crabs (*Cancer irroratus*), and drills (*Urosalphinx*) as well as starfish are constant threats to the mussels.

The Oyster

The oyster belongs to the phylum Mollusca and the class Bivalva. There are two species of oysters cultivated in the Northeast — the indigenous American oyster (*Crassiosteria virginica*) and the imported European oyster (*Ostrae edulis*). Each animal is unique as to its requirements for optimal growth and its ability to survive and prosper in New England waters. The external anatomy and physiology of the oyster is very similar to the blue mussel. There is, however, a major difference between these two members of the class Bivalva. The mussel can exist for a relatively long period of out of the water, the oyster cannot. It is true that an oyster, especially a *Crassiosteria virginica*, can survive for several hours out of the water by employing many of the tricks that a mussel uses. However, nature has not provided the oyster with all the attributes that it would need to colonize this new environment. For this reason, there is no oyster band analogous to the mussel band in the intertidal zone, nor will one likely find oysters just under the waters edge at low tide. The oyster cements itself thoroughly to the substrate where it literally sets and it is there that it will spend the rest of its life. Neither the American nor the European oyster can tolerate temperature extremes as well as the mussel. Exposure to sub-freezing winds in winter or blistering heat during the summer presents a stress that would kill all but the most hearty oysters.

The *Crassiosteria* is much more tolerant of cold than the European oyster. There are reports of *Crassiosteria* being frozen into blocks of ice with apparently little harm once they were thawed out. The same cannot be said for the *Ostrae*. This cold tolerance is a major factor in growing oysters. As winter approaches, the oysters must be put down for the winter or over wintered. This process is very time-consuming and expensive. It often involves one or two divers and several days.

The American oyster thrives on slightly brackish water (15 parts per thousand — 0/00) but is relatively slow growing. They do not do well when placed in a truly marine environment (35 0/00) and thus are confined to estuaries and growing ponds. Since estuary land is at a premium in our area and because of the many problems encountered in estuaries, a new type of oyster was required which could grow in the marine environment.

The European oyster was just what the growers wanted. It is capable of attaining a marketable size

(50 to 60mm) in two or three years. Since this type of oyster would have to be introduced into the area, a struggle developed between the people who favored the introduction of the *Ostrae* and those who opposed it. One side argued that since the *Ostrae* could not reproduce in our cold waters, it represented no threat to the *Crassiosteria* and should be allowed as a means of developing the aquacultural industry. The other side maintained that if the European oyster were grown continuously in the colder climate, it would eventually acclimate to the cold waters and would develop the ability to reproduce here. This would result, it was felt, in the competitive elimination of the *Crassiosteria* because it was simply a slower growing animal. After much debate the *Ostrae* was introduced and at present many growers produce both oysters jointly.

The oyster is a filter feeder with an internal anatomy amazingly similar to the blue mussel. Because it lives in the same area, eats similar foods, and has a similar make-up, the oyster has many of the problems that plague the mussel. It is subject to parasitic infections and will produce a pearl in certain conditions in response to these infections. In the case of the oyster, the pearl may be of considerable value. Since the oyster will consume the *Gonyaulax* organism it is subsequently another cause of PSP in people.

The oyster is enclosed in two half shells and is therefore a bivalve. The two shells are noticeably different in shape. The left valve is flat and the right valve is convex. There is a pronounced umbo or bump with growth lines radiating outward from it. The presence of this umbo is so distinctive that it marks a particular developmental stage in the oyster's metamorphosis. The two types of oysters (*Crassiosteria virginica* and *Ostrea edulis*) are markedly different in their adult morphology. The *virginica* is shaped like a shoe horn being two to three times as long as it is wide. The *edulis* is much more rounded, with the length and width ratio being close to one. This difference in shape requires different mesh sizes during grow out of each species.

Finfish Farming

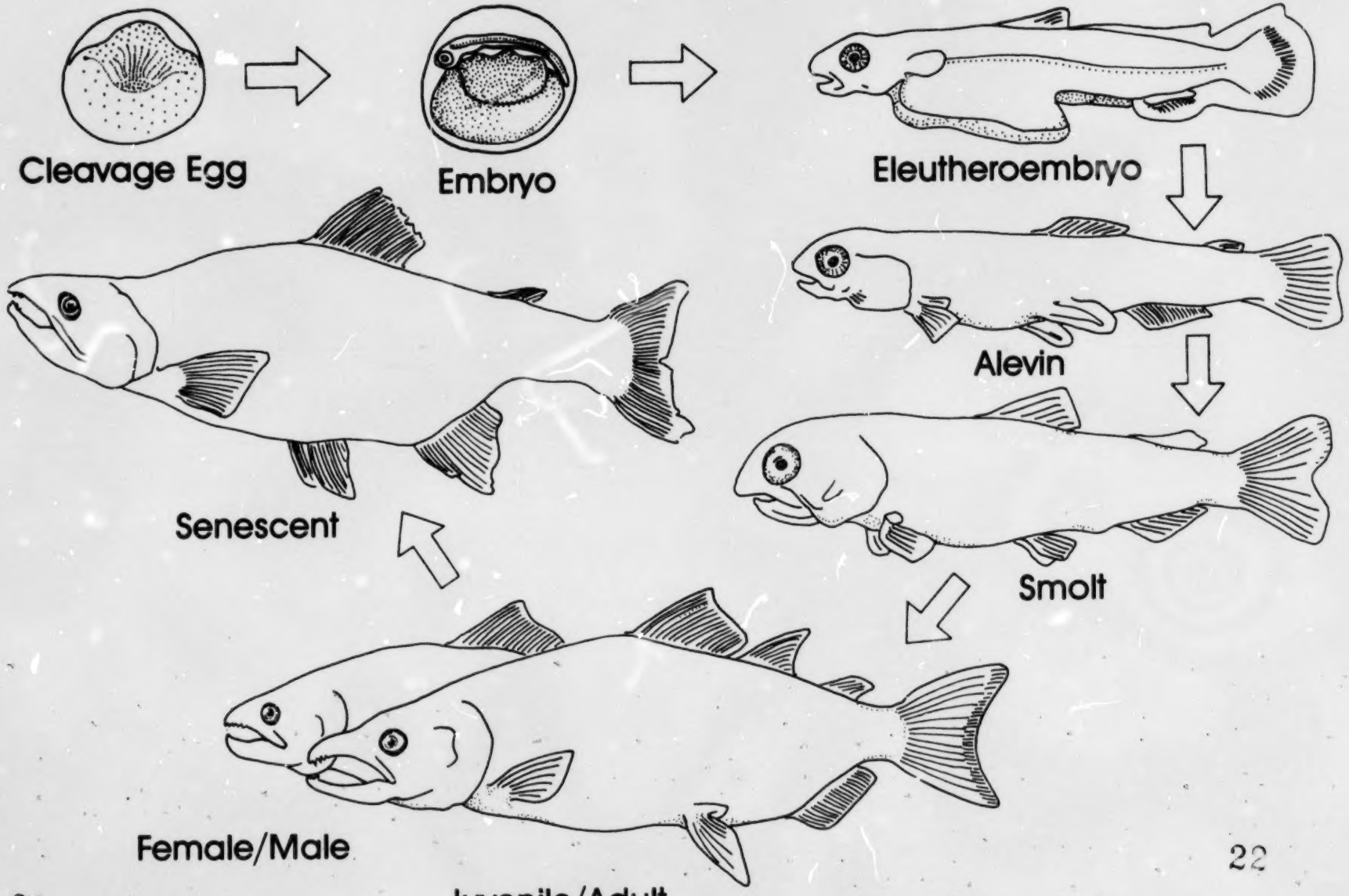
Finfish belong to the phylum *Chordata* and the class *Osteichthyes*. They are mobile and inhabit both the fresh and marine waters. Upon first glance, they resemble humans more than shellfish. Fish, after all, have parts we easily recognize: backbones, eyes, a nose, a mouth, a very human-like digestive system and many have bones that bear a striking resemblance to the bones in our hands and feet.

In the Northeast, various people have cultivated several basic types of finfish: Rainbow trout (*Salmo gairdneri*), Brown trout (*Salmo trutta*), Brook trout (*Salvelinus frontinalis*), Atlantic salmon (*Salmo salar*), and Coho salmon (*Oncorhynchus kisutch*). At the present time, no one has attempted to culture either the channel catfish (*Ictalurus punctatus*), the Milkfish (*Tilapia*) or the Pike (*Esox*) though all these species have been successfully cultivated for many years in other parts of the world.

In a hatchery situation, the problems of over-crowding, stress-induced diseases, and bacterial and viral infections are present regardless of whether one is producing fish fry or oyster spat. The problems that fish farmers have growing a fish crop are very similar to the problems a land-based farmer has growing a crop of pigs, sheep, or rabbits. Both types of animals must receive a nutritious diet, they must be separated from their own waste products, and they must not be unduly stressed if they are to have optimal growth rates. The difference between the agriculture farmer and the aquaculture farmer is the ease with which these requirements can be met. Since fish dump their wastes directly into the water, it is necessary to change or flush the water regularly. A sheep can be fed by walking out into the field and dropping a bale of hay which the sheep can eat until the hay is gone. The fish farmer is faced with the problem that fish must be fed during a specific time and any of the unconsumed feed will sink to the bottom and provide an excellent substrate for bacteria which may lead to a problem later. Overfeeding is less of a problem with shellfish. They can be fed continuously with little adverse effect. Fish, however, are stressed every time that they are fed so the feedings are kept to a minimum. It has also been shown that overfeeding a colony of oysters and mussels does not predispose the colony to a bacterial infection as is so often the case with fish.

Stress is a major factor which must be considered when raising the more developed fish. One of the manifestations of this advanced development is an increased susceptibility to stress induced by overcrowding, thermal shock, poor nutrition, and bacterial infection. Whenever an organism is grown at high population density it is more subject to infections than an animal grown at lower population density. This propensity demonstrates itself both by a direct increase in mortality due to diseases and an indirect mortality induced by secondary infections. Both the shellfish and the finfish share the first problem. The second problem is of particular interest for the fish farmer. Fish are more subject to abrasion when raised in a confined area than are shellfish. Even healthy adult fish succumb to a secondary infection induced by mechanical abrasion. Once shellfish reach a certain size, mortality rate drops off substantially, unless there is some catastrophe.

Adulthood is no sanctuary for the fish. Finfish must be held in a very intensive aquacultural system for their entire lives as opposed to a shellfish which can almost be "dumped into the bay." Therefore, finfish farming represents an extensive aquaculture. The finfish farmer has a



Successive developmental stages of the salmon.

substantial investment in each adult fish. The loss of a single animal is to be avoided if at all possible, so the fish farmer will more than likely have course to use antibiotics in an attempt to keep animals healthy. The problem with this approach is that feeding the antibiotic is the most effective way to administer the drug — bathing the animal in the drug being ineffective, and injection being too stressful and time consuming. However, there are very few antibiotics which are both effective against the disease and certified safe by the federal government.

The Lobster

The largest phylum in the animal kingdom is Arthropoda, which includes animals with jointed legs. The American lobster (*Homarus americanus*) belongs to a group of arthropods called Crustaceans. The lobster is distinguished from other crustaceans, such as the crabs, by the large abdomen. It has five pairs of legs. This characteristic of having ten legs provides the name decapoda or ten-leggers to lobsters, crabs, crayfish and similar relatives. The first pair end in pincers and are larger than the rest. The lobster is usually right-clawed; that is, the large crusher claw is on the right while the smaller pincher claw is on the left.

While living on the bottom, the lobster moves easily on the tips of its slender crawling legs. During this process, it keeps its large claws extended forward to reduce resistance as it moves through the water. Since the lobster weighs less in the water than in the air, its movement in the water is much more graceful than the strained crawling we observe on the sink or on the table. While surveying its territory, the lobster maintains forward motion primarily through the rhythmic beating of its swimmerets.

If startled or in danger, the lobster can swim rapidly by flexing its powerful abdomen or tail. This flexing results in a fast, backward movement of the lobster with its legs streaming behind.

The lobster can be found in the Atlantic coastal waters and in estuaries from eastern Canada to the middle Atlantic coast, from Bell Isle in Labrador to North Carolina. It is commonly found in the waters of the New England coast where it is most abundant. The lobster is a bottom dweller. It lives among rocks and in mud burrows seeking the protection of seaweed, kelp, and other marine growths. The lobster, as far as it presently known, is relatively non-migratory, only moving off-shore into deeper waters during the cold months, and returning to the coastal shoals during the spring and summer months.

Lobsters reproduce by the physical union of two sexes. The female can only mate shortly after molting. She has a special organ called a sperm receptacle, where she stores the sperm from the male until the eggs are ready to be extruded. The sperm remains vital within the female's receptacle for periods in excess of a year. When the female is ready to lay her eggs, she turns on her back and flexes her abdomen. The eggs then flow from her genital openings at the bases of the second pair of walking legs over the receptacle where the eggs are fertilized by the previously stored sperm. The fertilized eggs become attached by a natural adhesive to the female's swimmerets. The female carries these eggs until they are hatched. She is called a "berried," "seeder," or "spawn lobster" during this period. The eggs usually are cemented in bunches to the swimmerets and one female may carry from 9,000 to 100,000 eggs.

The young go through a change and after hatching bear very little resemblance to the adult. The little lobster has a tiny rounded body. The length of time required for a typical young lobster to grow to maturity is about 208 days. It is estimated that during this period, a lobster will grow from a width of one millimeter to five centimeters. The life of a lobster usually ranges from three to fifty years or more, attaining a 500 gram mass (about a poind) in four to seven years.

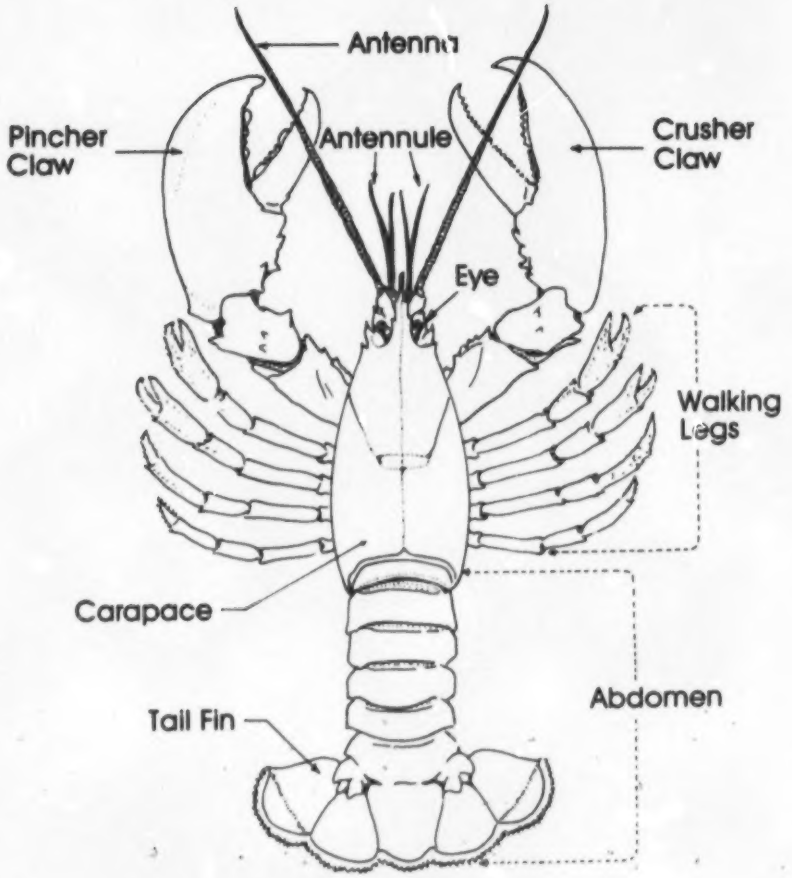
The lobster is completely enclosed in a more or less continuous hard-shelled coveirng, hinged like a suit of armor. This hard shell is incapable of expansion; so, in order to accommodate increased size due to growth, the lobster has to shed its shell from time to time. It does this by backing out of its shell.

The lobster gives warning of an approaching molt several days in advance. A black line appears just within the back margins of the outermost segments of the swimming legs. This line changes to white then to red two or three days before the molting. Fishermen call the lobster in this condition a "shedder."

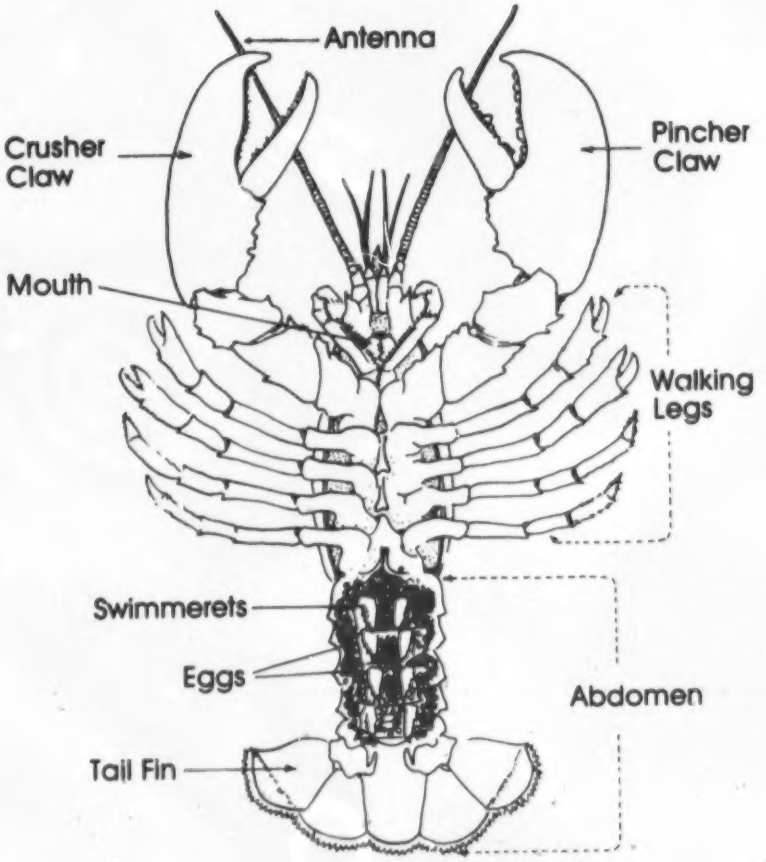
At the moment of molting the top shell or carapace begins to move away from the abdomen and a crack appears in each side of the shell going almost to the mouth. The back part of the body begins to stick out through the gap. At this time, the lobster usually lies motionless, but it can swim quite actively if disturbed. The carapace is lifted higher and the rear walking legs begin to be withdrawn.

The only time the female lobster can be impregnated is when she has freed herself completely from her old shell. The lobster remains soft for a short time only, for within two days the new shell has hardened. Molting is an exhausting process — and dangerous because the lobster is defenseless at this time.

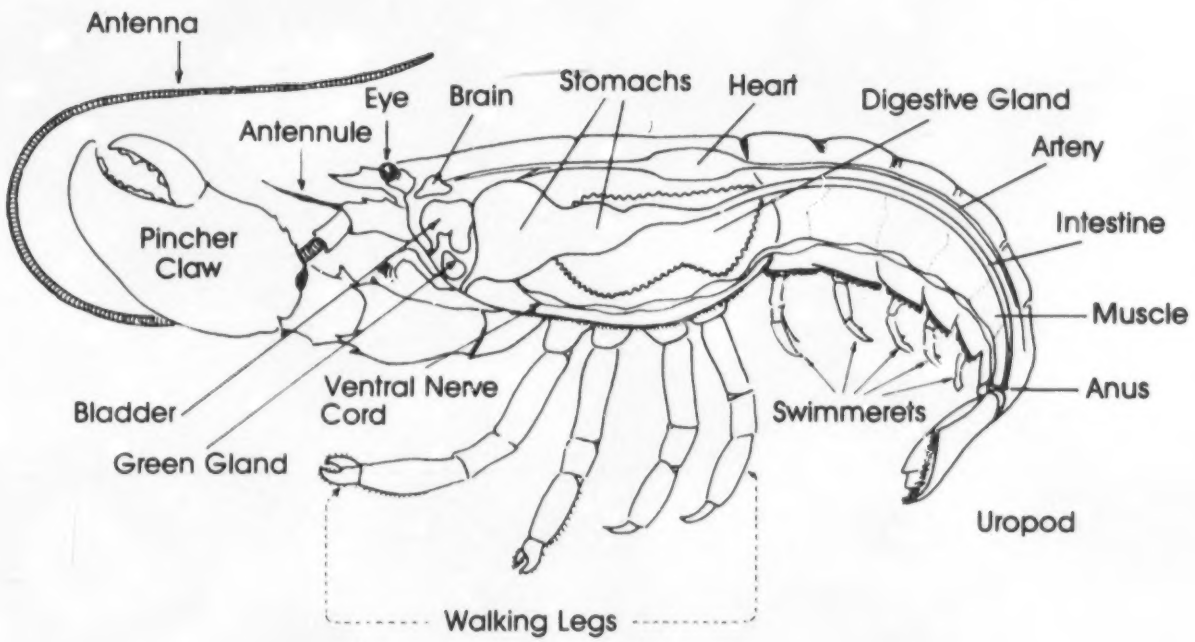
The American lobster has two kinds of sense organs — a pair of eyes and two pairs of antennae covered with sensory hairs. Though the eyes are prominent because of their size, the lobster's vision may not be very keen and not very useful in bright light. Like the eyes of insects, those of the lobster are compound, with perhaps as many as 14,000 lenses. There are suggestions, however, that



Lobster: Top View



Lobster: Bottom View



Lobster: Side View

different facets on the lobster's compound eye are sensitive to different light intensities. This might mean that the lobster's sight is more effective than previously thought.

The function of smelling is performed by the olfactory hairs, which are found all over the lobster's body, with concentrations on the first antennae and mouth parts. These hairs are sensitive to chemical and tactile stimuli. As the currents send fine particles from live prey or from decaying organic matter, these olfactory hairs catch the scent and lead the lobster ot its food. The lobster uses its pincers to rip and tear its food and push it into its mouth.

A lobster can cast off a limb and grow a new one in its place. This serves as a means of escape from its enemies. The growth of a new limb begins at once with the formation of a bud beneath the scar left by the breaking off of the old limb. The bud takes on the shape of a limb, indistinguishable from the former limb after a few molts.

The lobster fisheries of Northern New England yield a catch of millions of kilograms annually. These are exclusively lobsters called "selects" which are lobsters caught inshore and which weigh under one and one-half kilograms. The most abundant size in this group is the "chicken" lobster which has just molted into the legal minimum size. "Chickens" weigh 500 grams or less. Maine prohibits the taking of large lobsters from offshore waters by draggers.

Inshore lobsters are caught in traps set on the ocean floor from twenty meters to several kilometers apart in from five to fifty fathoms of water (1 fathom is 6 feet or about 2 meters). The traps are usually baited with fish cuttings to attract the lobster. A new pelleted bait is currently being developed which could be more convenient and less expensive. The 21.4 million lobsters caught in Maine in 1964 was the effort of 754,000 traps.

Lobster may be placed in lobster cars or lobster floats to await sale. These are large, compartmentalized wooden boxes which lobstermen moor near their boats. The lobster car is divided into segments. The lobsters are checked for shell condition and size and put into appropriate compartments. Some lobsters are held in lobster pounds, which attempt to provide a "natural home" and are fed until sent to market. Lobster pounds are sometimes dammed off coves along the coast. They have the advantage of being naturally cleansed by the changes in the tide. However, the risk of disease among lobsters stored in pounds is high so, therefore, the lobsterman runs the constant risk of losing the catch while holding them awaiting the higher prices of winter.

The lobster, along with prawns or shrimp (*Pinaeus*), are likely candidates for intensive aquaculture in the Northeast. The lobster is a marine organism as is the prawn, although certain shrimp are freshwater organisms. The largest single problem encountered when cultivating either of these groups of crustaceans is the fact that they are cannabalistic. A second problem, especially when dealing with the lobster, is its slow growth rate. In 5°C water it may require seven or eight

years for a lobster to reach market size. Researchers in Martha's Vineyard have succeeded in reducing the growth times in half by growing the animals in warmed water, but this induces a thermal stress and predisposes the lobster to bacterial infections. It was also determined that the meats were not flavorful and lacked the desired texture, although this problem might be overcome by "finishing" the animals colder waters.

It appears that the idea of reducing the time required to reach market size by elevating the water temperatures needs more work. Emile Plante developed the idea of putting individual lobsters into their own cylindrical containers which were mounted one on top of the other and affectionately known as the lobster "Hilton." By keeping the animals out of sight of other lobsters the aggressive nature of the animals was reduced and cannabalism was impossible. This design did not reduce the interval of time required to produce marketable animals but could be a low cost solution to the problem of cannibalism.

Algae Culture

At present the only form of intensive algae culture which is practiced in the Northeast is growing algae as a food for shellfish in hatcheries. Algae can also be grown commercially and is used in a variety of ways. It can be harvested as a food directly as is Irish Moss, *Chrondus crispus*, and the Japanese delicacies Nor, *Porphyra*, and Dulse, *Rhodymenia*. Many of the red, green and brown seaweeds can be used in salads. Because algae contains a complex mix of minerals, it has been used as a fertilizer for hundreds of years. Algae also produce a wide variety of chemicals which are indispensible in our modern society, especially emulsifiers, which are used for everything from ice cream to beauty creams.

Algae can also be harvested and converted to alcohol or dried and burned directly. The larger algae such as kelp, *Laminana*, and certain aquatic plants such as duckweed, *Lemna*, and water hyacinth, *Eichornia*, are especially promising in this respect. Since these aquatic plants are extremely fast growing, they use up a great deal of nutrients in the water and are therefore helpful in purifying that water. They also share the ability to bioconcentrate certain toxic chemicals within their bodies and therefore offer a possible route for the detoxification of polluted waters.

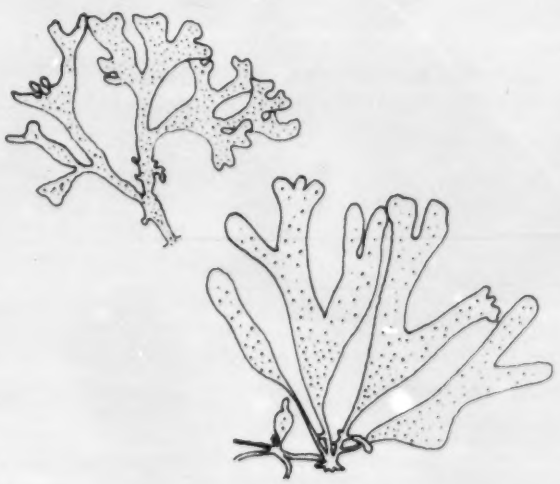
Single cell algae are receiving increasing attention as a source of protein referred to as Single Cell Protein (SCP), and many nutritional studies have been conducted using this type of algae. What one can do with algae is limited only by imagination and budget. Profit figures from some of the experiments in growing algae indicate that this source will soon become a valuable addition to the other aquacultural enterprises.

Other Aquacultural Species

There are several other species which have been cultured in the Northeast. These species include the Bloodworm (*Blyeera dibranchiata*), Eels (*Anguilla*), Frogs (*Rana*) and both bay scallop (*Argopecten irradians*) and the deep sea scallop (*Patinopecten yessoensis*), as well as the European scallop (*Pecten maximus*). Much more information must be gathered about the life cycles of these animals before they will be suitable for an intensive aquacultural system. But each species holds its own unique promise for the future.

Certain members of this list are very difficult to cultivate, especially the scallop, because of its extremely delicate juvenile stages. Other species such as he eels have been harvested in an extensive system for the last hundred years in this country.

As anyone who has read *In Search of the Blue-Eyed Scallop* by Euell Gibbons will testify, there is almost nothing that is safe from the foragers in the Rocky intertidal zone in the Northeast. The slipper limpet (*Crepidula*), sea urchins (*Strongylocentrotus*) and even the common periwinkle (*Littorina*) will all be considered deliciously fair game for the ardent epicurean forager. Even though these animals are not, as of yet, intensively cultivated, the first step towards cultivation is a demand from people.



Mussel Dissection

The dissection of shellfish requires care because mussels have few colored organs. There are, however, many things that can be readily seen and the observations made during dissection can serve as the basis for discussion.

The dissection deals specifically with the Blue mussel, *Mytilus edulis*, but will apply equally well to many of the other bivalves (oysters — *Ostrae edulis, Crassiosteria virginica*, soft shell clams, *Mya arinaeres*, hard shell clams, *Mercenaria*, and bay scallops, *Aquipecten*). Specific mention of certain other bivalves is made throughout this dissection and if a specimen of one or more of these animals is included, the scope of the experience will be increased. It is, however, not necessary to have any other shellfish present to conduct a dissection of the blue mussel.

The mussel should be opened and dissected in salt water to reduce the damage to the gill and mantle structures, and the initial cutting of the adductor mussels requires a sharp knife. For these reasons, it is suggested that the teacher provide students with precut specimens or allow two to three animals for the student to "practice on" prior to starting the dissection. The problem with bivalve dissection is that one does not know what is inside the shell until it is opened and careless opening of an animal will destroy delicate structures.

External Anatomy

There are several things to observe about the outside of the mussel. Figures for this dissection are found in the pocket. You will want to refer to them as you read the following background on mussel anatomy. The first is the presence of concentric rings on the shells. These are growth rings and there is a direct relationship between the spacings between the rings and the environment, exactly analogous to a tree's ring system. The two valves of the mussels are equal in size; however, shell equivalence varies among the bivalves. Scallops and oysters exhibit a marked difference between shells, the right valve being flat and the left convex. Shell morphology reflects growth pattern and is characteristic of each species, though pronounced irregularities can occur under disease conditions.

The next thing to observe is the presence of the byssal threads, especially apparent if the mussel was collected along with the substrate. These threads are laid down within a few minutes and provide the mussel with the ability to hold on. If your catch of mussels includes some still attached to their substrate, it might be profitable to have the students try to pull the mussels free. Care should be used in handling the shell, however, as the edges can be quite sharp.

Some mussels collected may have small holes in their shells. These holes may go partially or completely through the shell, and are the work of drills which attach themselves to the shells. The drill rasps the shell away until it can feast on the helpless mussel inside. Drill holes are very regular in shape and are the size of a pencil point.

The last external feature to note is the presence of a cartilaginous, rubbery material on the back of the shell. This acts like a hinge and allows the mussel to open the two way valves by a pivoting action which will be discussed later. If the organism is healthy, none of the internal organs, mantle, gills, siphon, or foot should be protruding from the shell.

Internal Anatomy.

Orient the mussel in the hand as shown in Figure 4 of the pocket section. Familiarize yourself with the four exterior areas (anterior, or head end; posterior, or rear end; dorsal, or top area; ventral, or bottom area) and sides (left and right valves, see Figure 3). If mussels have been cooled at 2-3°C for a half hour prior to dissection, adductor muscles will be relaxed and the process of opening shells will be simplified. Insert a flexible knife at the area shown in Figure 4, and gently slide it across the interior of the upper, left valve. Care should be taken to keep the knife blade from damaging the internal organs, which will be located in the central region of the mussel. Three major muscle groups will have to be severed before the shell can be easily lifted to expose the organs: (1) posterior adductor, (2) foot retractor muscles, and (3) anterior adductor muscle. The posterior is largest in size, and the most easily cut. The anterior adductor may be located and cut after the other two muscle groups have been cut, allowing the valves to gape. If there is not a marked relaxation following your cutting motion, you may have to repeat it, always seeking to avoid damaging internal organs, particularly the delicate gills. The hinge ligament is positioned so that the valves are open in a relaxed mode. The shells or valves are held closed by the constriction of the adductor muscles. When these are relaxed, the valves will naturally open (see Figure 5 and 6 of the pocket section).

The dissector will immediately be confronted by the unfortunate fact that almost everything inside a mussel is the same color. Also, many organs are similarly shaped and tend to overlay each other. Before examining the organs, you should examine the shell interior. When all muscles have been severed, lift the left valve up and locate the pallial line (see Figure 7), which marks the place where the mantle attaches. The inner layer of the shell is completely different in texture and color from the exterior portion of the shell. This is because the shell is not one material but is composed of layers of different materials. If it were possible to observe the cross-section of the shell under a microscope, three distinct layers would become apparent: the inner or peristracum layer, composed of conchiolin (mother of pearl), and two outer crystalline layers composed of calcium carbonate and conchiolin.

The location and number of the adductor muscles is highly variable among bivalves and can be used as an identification aid when a dried shell is located on the beach.

In certain bivalves, the mantle is fused ventrally and attached to the shell, but in the mussel, the mantle is not fused ventrally, nor is it attached to the shell. Because of this distinction, it is possible to identify dried shells of different bivalves by the presence or absence of the pallial line. It should also be noted that in certain bivalves, this pallial line is deformed into a pallial sinus by the presence of the exhalent siphon. A dried shell can tell you a lot about the animal that lived in that shell. It can also be used as a rough identification aid to separate certain members of the class Bivalva such as mussels from clams. The shape of the pallial sinus gives you an idea of the importance of the exhalent siphon to the animal. Burrowing animals depend upon this organ more than non-burrowing animals. The number and location of the adductor muscles can also be used as an identification aid. It is suggested that to fully demonstrate the differences described above, the teacher should obtain a dried scallop, mussel, and clam shell.

With the left hand shell removed, those structures depicted in Figure 8 (pocket section) should be visible. The structure which completely surrounds the body of the organism much like a blanket is the mantle. One of the functions of the mantle is the production of new shell material, thoughit can assume several different functions depending upon the species of the animal and the stage of development. In the mussel, the mantle is not fused along the ventral border. You may find that in cutting the adductor muscles to open the valves you cut the mantle, with portions adhering to both valves. Many bivalves such as the scallop and oyster possess a well-developed fold of the mantle known as the velum or pallial curtain. This often possesses sensory cells along the marginal edge. The velum acts as a food gathering device, "sweeping" the water into the shell.

The internal organs of the bivalve can be divided into groups by their functions: (1) respiring and/or eating, (2) locomotion, (3) reproduction, and (4) musculature. Each of these organ systems may be thought of as a separate entity for the purpose of this dissection, but it must be remembered that several organs may function together at any one time.

The gill is actually composed of two W-shaped ctenidium, fused along the dorsal surface (see Figures 8, 9, 10 of the pocket section). After examining the left gill in place (for location, refer to Figure 7 of the pocket section), you may remove it by lifting and cutting carefully along its entire length. You will find that it is attached to the main mass of organs along a rather straight line from the mouth area to the posterior adductor muscle. Care should be exercised not to accidentally remove the kidneys while doing this (see Figures 11 and 12 of the pocket section). When the gill is removed, the digestive organs should be easily exposed, although the dissector should not plan on exercising the entire digestive tract, as the organs are positioned in layers.

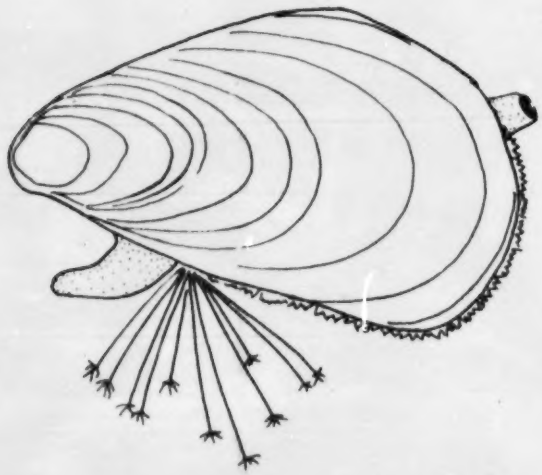
The digestive system of bivalves consists of an esophagus, stomach, digestive diverticulum, midgut or intestine, and hindgut or rectum. Water is drawn over the ctenidia and the food particles are sorted out and covered with a mucous material. This food package is carried towards the labial palps and the mouth by tiny hairlike projections from the cell. These projections are called cilia and their beating creates a current directed towards the mouth. On reaching the palps, the food is sorted. The material which is small enough to be accepted passes onward and the larger material is passed outward towards the periphery of the mantle. The mucus-bound food enters the mouth from the oral groove of the palps and moves to the stomach via a short escophagus. Once the food reaches the stomach and intestine, it is subjected to mechanical abrasion by the crystal style and chemical degradation by the enzymes and chemicals in these organs. Food is sorted by ciliary ction and conveyed to the digestive diverticulum and eventually is excreted at the anus into the cavity of the shell. Here the feces (the matter which has passed through the digestive tract) and the pseudo-feces (the material which was rejected at the labial palps) are both discarded through the excurrent siphon to the outside.

The foot is the organ of locomotion. In animals such as the soft-shelled clam, the foot is used to borrow. Burrowing is accomplished by extending the foot through the mud and then causing the terminal (end) portion of this organ to swell, acting as an anchor. When the foot is secured, the retractor muscles which normally retract the foot are contracted, and since the foot is secured, the body moves toward the foot rather than vice versa. Certain bivalves such as the hard shelled clam have developed a wedge-shaped foot to facilitate this burrowing action. This wedge-shaped foot is so pronounced that the animal derives the name of its order from it — wedge or hatchet foot, *Pelecypoda*.

As the organism developed from the burrowing to the sedentary mode of life, it developed a means of securing itself to hard substrates, called the byssal structure. Since the mussel is a creature which clings to its substrate, you would expect to observe this byssal apparatus. Externally, the threads are easily apparent; internally, they can be seen to originate from the foot structure proper.

When the organism became more sedentary, the size of the foot decreased and the size of the byssal threads increased. The byssal apparatus functions in two ways to secure the animal to its environment. In the case of the mussel, threads are produced which act as guy wires to secure the animal. In the case of the oyster, a gland produces a cementing agent which secures the animal directly to its substrate. The mussel foot is attached to the shell by a series of retractor muscles, and it is connected to the other organs by a blood and nervous system. It should be possible to locate the foot, which you will probably find "tucked" forward, almost under the mouth apparatus.

The gonads usually lie in the foot below the visceral mass, and depending upon the species and time of year, their size can be highly variable. Many of the bivalves are functionally hermaphroditic — forming sperm and ova in different parts of the same gonad. Other bivalves can change their sex in response to the need to balance the number of males and females within the population. This sex change can occur either as a single event or several times during the lifetime of the animal. Fertilization occurs externally, although the animal may hold the fertilized eggs within the shell (supra-granchilal cavity) in response to adverse environmental conditions. The hermaphroditic nature of many of the bivalves is clearly demonstrated in the scallop, where the fully developed gonad is observed as a large creamy white testis lying dorsal to a bright orange or red ovary. In the mussel, the gonad is one color.



After you try the dissection yourself, duplicate and distribute the mussel dissection figures from the pocket to your class. You may want to use three days for this dissection. Day one could be used for introduction and external anatomy along with comparison with other bivalves using either living organisms or their dried shells. Day two could be opening practice along with an overview of internal anatomy with dissection groups working along with the teacher. Day three could be complete dissection of a whole mussel and/or an additional organism such as an oyster or follow-up discussion.

Mussels may be collected or purchased from the supermarket or fish market. They may be kept a week or so in the refrigerator without water or returned to the refrigerator after partial dissection to wait for the next class. There is no need to use any kind of preservative. Be sure you are aware of local and state ordinances and pollution conditions before you collect mussels. More information can be obtained from the State Department of Marine Resources.

A Note On Safe Collecting Of Marine Organisms:

If you plan to collect specimens, it is always a good idea to check first by telephone with the Marine Patrol Officer of the Department of Marine Resources who is responsible for the town where your field trip will take place. There may be a local shellfish ordinance with which you must comply, a ban on some species due to Red Tide, or the area may be closed due to pollution of other types.

If the growth conditions of light, temperature, nutrient level, and salinity are in certain proportions, there may be a bloom of Red Tide. This occurs when the dominant phytoplankton species which multiply rapidly under these ideal growth conditions is *Gonyaulax tamarensis*. These phytoplankton produce chemical substances within their cells that are toxic to animals. Filter feeders such as clams, mussels, and oysters concentrate the toxin in their systems. Whelks, snails, and others that eat the filter feeders also become toxic. When a person eats these creatures, he or she may suffer from paralytic shellfish poisoning (PSP) which can result in illness and death. Fish, crabs, and lobster contact this phytoplankton only indirectly, do not concentrate the toxin, and are safe to eat.

It is illegal to collect lobsters in any stage of development — larval through adult. Other marine organisms may be collected without a license when collected in small quantities. It is enormously important if you feel it is necessary to collect, that you stress conservation and make plans for effective, humane transportation of the living things back to school.

Water and Nutrient Passage in Mussels

Place a live mussel in a container of sea water and observe its movements. When the mussel begins to filter, add some carmine powder, obtainable from science supply houses. Observe the filter currents. Then determine where water enters and where it exits. After about twenty minutes dissect the mussel carefully and observe where the carmine powder has collected.

Eating Mussels

There are many foods eaten throughout the world which are seldom eaten in America, like mussels. It seems that most Americans prefer a hamburger and french fries to french fried squid and seaweed soup. But, how many Americans have ever tried squid or seaweed?

Have your class investigate and discuss the various types of food consumed in foreign countries that are seldom eaten in America. Next decide which ones might be available to you and try them as a class. Many specialty foods can be purchased at grocery stores or you may be able to get leads as to where they can be found. Several good recipes for mussels follow.

Recipes

Make sure all the mussels are alive (they close tightly when touched). Wash them well and pull of the byssus threads or "beard."

Steamed Mussels

2 quarts cleaned mussels
1 onion, chopped
1 cup dry white wine or
1 cup water plus 1/4 cup
vinegar or 1 cup apple cider

1 bay leaf
parsley
1/4 tsp. thyme*
1/4 tsp. pepper
3 tbl. butter*

Put all ingredients in a large covered pot and bring quickly to a boil. Shake the kettle often so that the mussels cook evenly. Steam over medium heat 5-6 minutes or until shells open. Remove whole mussel meats from shell to eat — good with melted butter and lemon juice.

Stuffed Mushrooms

36 fresh mushrooms, at least
2 inches (5 centimeters)
in diameter
1 large clove garlic, chopped
6 tablespoons butter or
margarine
1 medium-sized onion, finely
chopped

1½ cups (180 grams) fine
dry bread crumbs

1 cup (250 grams) cooked,
chopped, and drained
mussel meats (canned, or
fresh steamed by method
above)
3 tbl. sherry*
1/4 tsp. finely crumbled
oregano

oregano*
Salt and pepper to taste

Wash mushrooms and pat dry on paper toweling. Remove stems and finely chop half of them (use remainder another time in a stew or an omelet).

Saute the garlic in butter about 1 minute or until soft; toss in chopped stems and onion; saute until golden. Remove from heat, add bread crumbs, mussels, sherry, and oregano. Mix well, taste, and add salt and pepper.

Salt mushroom caps inside, then spoon in stuffing. Butter baking pan and put mushrooms on it, stuffing side down. Preheat broiler and broil mushrooms about 5 inches (10 centimeters) below heat for about 2 minutes, or until hot and beginning to soften. With spatula carefully turn each over and broil until light golden brown. Serve piping hot.

Creamed Mussels with Dill

2-3 liters cleaned mussels
1-2 tbl. margarine or 1/2-1 tbl.
each butter and oil
2 tbl. whole wheat pastry flour
1 cup milk

1/4 tsp. pepper*
1/2 tsp. salt*
1/8 tsp. paprika*
dill

Put mussels in large covered pot with small amount of water. Bring quickly to a boil and steam 5-6 minutes, shaking kettle so mussels cook evenly. Remove meats from shells.

Melt margarine or butter and oil in saucepan. Add flour and mix without browning flour. Add milk gradually, stirring rapidly to make a smooth blend. Add pepper, salt, and paprika. Simmer ten minutes. Add 1 tbl. or more minced plain dill or a few crushed dill seeds. Add mussels. Serve plain or with rice.

* One tsp. is about 5ml, one tbl. is approximately 15ml

A Note on Nutritional Characteristics of Blue Mussels as Compared to Beef Steak

3.5 ounces (100 grams) raw meat	Common blue mussel	T-bone Steak (choice)
Calories	95	395
Protein	14.4 grams	14.7 grams
Fat	2.2 grams	37.1 grams
Carbohydrates	3.3 grams	0.0 grams
Calcium	88 milligrams	8 milligrams
Phosphorus	236 milligrams	135 milligrams
Iron	3.4 milligrams	2.2 milligrams
Iron	3.4 milligrams	2.2 milligrams
Thiamin	0.16 milligrams	0.06 milligrams
Riboflavin	0.21 milligrams	0.13 milligrams

SOURCE: United States Department of Agriculture Handbook No. 8, *Composition of Foods, December 1963.*

Crustacean Study

You may wish to establish an aquarium with crayfish in it so the class may observe the external anatomy and behavior of a decapod very similar to the lobster. Try the activities described below.

You may find that a live lobster is unattainable or very expensive in your area. A crayfish is the common freshwater crustacean cousin of the American lobster. If you live near a pond or stream you may find an abundant supply of them. These organisms are primarily nocturnal in their feeding and may be observed close to shore in the early evening hours if one were to look using a flashlight. Many times divers who might dive in the local lakes and ponds have observed their behavior and have picked them up quite readily. Perhaps you know a diver who would be willing to collect them for you. The crayfish could also be taken with a trap which may be an interesting project for the class. It is constructed as follows: A rectangular box of any convenient size, 30 by 50 centimeters for example, is built of half centimeter mesh galvanized screen wire. A removable funnel should be made on one end of the trap. This is constructed of the same material and should extend about halfway into the trap and have a flattened opening about nine centimeters wide and three centimeters deep. A minnow trap can be used as well if you choose not to build one. This can be purchased in a sporting goods store.

The trap should be set in shallow water along a sloping bank and buried partly with mud or sand. The opening should face the shore line with the bottom of the funnel even with the bottom of the stream or pond. Some of the trap will project out into the deeper water. Any type of dead fish or raw meat will attract the crayfish. Secure this bait to the bottom of the trap with some flexible wire or string. This trap should be set in late afternoon or early evening and left overnight. If there are any crayfish in the pond, the trap should capture several of them.

Another option is to order these creatures from a biological supply house. The names and addresses of several companies are in the "Teacher Resources" section. They may be purchased living and the cost depends on their size. It is a good idea to plan for this activity several weeks in advance to allow set up time to take care of the crayfish. Small to medium crayfish are cheaper and easier to keep.

A forty liter aquarium is of sufficient size to hold two or three crayfish. First collect fresh clean pond stream, or lake water in covered containers. When you collect make sure you keep mud and other sediments out of the containers. Pond water will keep for an indefinite period of time and will be a source throughout the time you keep the crayfish. If there is no easy access to this type of water, you may use ordinary tap water. You must age this water allowing the water in the containers to stand for several days. This gives sufficient time for the chlorine to escape from the water and not harm our crustacean friends.

The next step is to set up the aquarium. Begin by washing coarse angular gravel to remove all dust and dirt. Clean all equipment, including the aquarium itself, with baking soda. Never use a detergent. Put gravel into the bottom of the aquarium and add about eight centimeters depth of pond water or aged tap water. A plastic cover is suggested to help keep evaporation down and to keep out things that do not belong in the aquarium. The same can be done for a divider if they are not available at the pet store. Place the aquarium in a naturally well-lighted area but never in direct sunlight.

Place several large rocks into each aquarium to allow the crayfish to climb out of the water. They do not require an air bubbler although you should change the water every week. Provide crayfish hiding places. You might choose discarded, clean plastic flower pots placed open end down. Cut a door to admit your crayfish.

When you obtain your crayfish, clean them off by rinsing them separately in a bucket of water before adding them to the aquarium. Give the crayfish several days to familiarize themselves with their new home before feeding them.

The crayfish may be fed small pieces of thawed, raw frozen fish. Use only unbreaded fish and feed sparingly. The size of the fish should be about half centimeter cubes. It is best to feed them on a regular time basis like in the morning on Tuesdays and Fridays. This will carry them through the weekend. They do not need feeding every day. Leave the food until they finish eating most of it — one day is usually sufficient. Remove any floating food or uneaten food after this or it will contaminate the water. You may even feed them separately from the aquarium. This can be an enjoyable activity for your students to watch:

Crayfish Feeding Observations

1. How do crayfish react when they are hungry? (Drop a little food in front of them.) Do not disturb them as they eat — just observe them.
2. How do they use their claws and mouth parts when they eat? Are they right-handed or left-handed?
3. Are they very defensive when they eat?
4. If one piece of food is dropped around several crayfish, which one eats first?

Crayfish Locomotion and Navigation

1. Crayfish have two types of movement. What are they?
2. Can crayfish climb very well? What legs do they use?
3. When are they most active? (morning, late afternoon, when are they hungry?)

4. On a day when crayfish are not being fed, wash off a few small rocks and set up an obstacle course in the aquarium. How do crayfish get around them? Do they climb over them?
5. On a feeding day, place a small clean plastic ladder against the wall of the aquarium. How do the crayfish get around this? Place some food at the top of the ladder. Will the crayfish climb the ladder? Which legs do they use? Do they use their antennae?
6. In a darkened room, place a flashlight on one side of the aquarium. Are they attracted to the light?

Handling Crayfish

A large fish net should be used to pick up the crayfish from the aquarium when first handling them. This avoids introducing contaminants from your hands and also prevents your friends from injury. Have a white enameled or drawer divider tray with about two cm of water in it. You may want to slant them slightly. The crayfish will walk up the bottom of the pan. When you pick up the crayfish (with washed hands), approach them from the rear behind their claws and pick them up by their backs gently but firmly. Crayfish do not bite, do not sting, and are not poisonous. They only pinch with their two large claws. The small walking legs will not harm you either. Crayfish are very active, move quickly, and are a lot of fun to observe.

Out of Water Activities

Be sure not to leave the crayfish out of water too long. Five minutes at the most, once a day would not be too much.

1. How many legs do they have? Are they paired? How are they located.
2. How many antennae are there?
3. Are there any exceptions to these numbers?
4. If you have access to balances, you may want to keep a record of their weights. This is a good metric exercise. Record their weight in grams and keep a daily record posted next to the aquarium. Do the crayfish gain or lose weight? You may want to carry this one step further and identify which ones gain or lose weight. This means you will have to label them.
5. Measure their claws, back, abdomen, and other parts in millimeters.

Labeling Crayfish

Handle the crayfish carefully. After removing from the aquarium, wipe off the crayfish with a soft towl. Also use the towel to cover the claws and head. Then mark them with white nail polish. Since it is too difficult to write names with a brush, you may want to use a number system to mark them on their backs.

Creative Writing

The objective of this activity is to have the pupil look more closely at the life of the crayfish in the aquarium and to have them put themselves in another animals place. You may add some interest by placing a cleaned bird cage mirror (made of plastic, not metal) in front of one of the crayfish and testing its reactions.

Materials:
- paper
- pencils

Procedure:
Give the pupils a list of topics related to the crayfish's life and discuss these topics to stimulate their imaginations.

1. If I were a crayfish in the tank...
2. Why I like my new home...
3. How I make my shelter...
4. What do I look like in the mirror?
5. My eyes are very different from other animal's eyes...
6. Where I used to live...
7. Who are my friends...
8. The strange things that observe me in my new home...

These questions can be reworded to suit the vocabulary of each group. After writing their stories, have the students illustrate them.

There are many activities that could be centered around the crayfish and its life cycle. You may want to separate the male from the females. They can be sexed like a lobster. The first pair of swimmerets are elongated in the male and shorter in the female. If the crayfish do reproduce, the female will become berried (carrying young) around February or March. The young will hatch out after about a month on the female's tail. After leaving the tail they will have to be separated or they will be cannibalized. Have the students devise a way to raise them.

Another critical time is in the spring. The crayfish undergo molting. The pupils may watch this process and want to report on it. The crayfish is very weak after this and may be eaten by the others. Remove any others but do not disturb the newly molted one as its new shell is very soft. It will harden in about two weeks.

Their life cycles are very similar to the lobster. You may substitute the anatomy and many of the activities in the unit on the lobster for the crayfish. You will quickly find that the aquarium and the crayfish will be a center of attraction in your classroom.

Aquaculture Equipment

Aquaculture is a new industry and has to design new equipment that best fits its particular needs. This area is open for new ideas on designing and building different types of equipment. Major problems encountered with different types of aquaculture species:

Oysters

1. Wintering—Because of the cold waters in Maine oysters have had to be relocated to warmer waters during the winters.
2. Silting—The trays have been located too close to the bottom and silt would get into them and foul them.
3. Cost-Diving has been the only means to relocate the trays and clean them. It has been very costly.

Mussels

1. Culling—A mechanical means has yet been developed to separate and sort the mussels in order to get the desirable size for market.
2. Pearls—The trematode worm, *Cymnophallus*, gets in the mussel and the pearl is formed around it.
3. Eider ducks—These birds find the farm, a haven for food, just right for the plucking.
4. PSP poisoning—(Red Tide) Mussels are the first to be effected by this organism.

Finfish

1. Birds—Birds like the delicate flavor of the brood fish and raid the holding pens.
2. Disease—Fin rot is the most prominent disease.

Lobster

1. Cannibbalism—The adult tends to eat anything in sight including their young.

Suggested Activities

1. Discuss the major problems encountered in Aquaculture farming.
2. Discuss how other farming techniques, such as land farming, can be used in water farming.
3. Individual reports: have students pick a particular species and report on its life cycle and problems encountered in farming it.
4. After a discussion on one of the major problems of farming:
   a. have the class brainstorm to design a piece of equipment that might be used in that industry, and
   b. have the class build a model of the piece of equipment.
5. Have an aquaculture farmer come to the school and discuss with the class the problems and benefits of their equipment.

The World Oyster Company Game

Overview. This is a simulation of the oyster culture industry in which the students act as growers. The purpose of the game is to demonstrate the major economic concerns that control the success of aquacultural operation.

This game assumes that an oyster crop requires at least three and one-half years (42 months) to mature to market size. Each turn represents one month. A complete game may require several class days to play. In any case, at least fifty turns are required to show most of the factors built into this simulation.

You will need about 25 copies of each form "Oyster Stock Form," and "Bank Balance Form" from the pocket and one pair of dice for an average size class.

Before play starts each student group simulates a company. In small classes companies would be composed of single students but a better size is three. All corporate decisions are made by majority vote of this board. When student groups are formed, ask each to select a company name. New companies are issued a $50,000 bank account as working capital. More money may be obtained from the bank, the teacher, at 1.5% interest each turn or month.

The teacher, in the role of banker, monitors play and helps to remind each company to pay its debts.

The First Three Turns

To help students adjust to the rules, the first three months of play simulate start up procedures of a sea farm. These are obtaining land and water rights, purchase of equipment and baby animals (seed) and borrowing money to increase the original investment.

The First Turn

During the first turn each company tells the bank its name and pays $200 for incorporation. Land may be leased for $4000 per year and a $500 license fee is paid to the Department of Marine Resources through the bank for water rights.

The teacher may want to use the blackboard or overhead projector to record and update bank balances and loan balances for each company. It is useful for discussion purposes to save these records to the end of play and then use a period to summarize what happened to each company. The first turn is January of the current year. Use this

turn to introduce the Bank Balance Form reproduced from the pocket.

The Second Turn

It is now February. Since this is a cold winter it is too early to put out and stock seed oysters and gear. If you have not yet reviewed the gear used in oysterculture with your class this is a good time to do that.

Companies will now order seed and Japanese Lanterns for growing seed. Lanterns are purchased new for $25 each. Lanterns can hold a different number of oysters depending upon their size. For example:

Size:	2-9mm	10-14mm	15-34mm	greater than 35mm
Number of oysters per lantern	1,000,000	100,000	10,000	1,000

Baby oysters (called seed) can be purchased in several size ranges. The larger sizes cost substantially more than the smaller sizes. This must be weighted with the fact that generally speaking, the larger animals are more likely to survive than are the smaller ones. The larger oysters must be held for a shorter period of time until they mature and can be sold. The choice of animals will be determined by cost, as well as other factors. It should be remembered that as the animals grow they will demand more and more and more lantern space. Growers will have to make provision for this event which can be done by holding funds in the bank to cover expenses as they arise.

Animals must be transferred to new lanterns as they grow and need more space. Growth rates for transferring are given below:

Size	2-9mm	10-14mm	15-20mm	35mm	jumbos
months before transferring to next size in summer growing months	3	5	6	*	*

* Mussels 35mm and larger are not transferred in this game

The grower must keep track of the sizes of each oyster group and the month that they change size. Companies have no spare time to buy new lanterns and get the crowded animals into new more spacious accommodations. If companies do not do this, they will lose 10% of the total number of oysters in that size group every month that it is not done. The growth rates of various size seeds along with cost is given as follows:

Size	2-9mm	10-14mm	15-20mm	35mm	jumbos
Cost/ thousand	$5.00	$10.00	$15.00	$20.00	$25.00
Time the animal must be held until maturity (in summer growing months)	24	21	16	10	8

Companies should be encouraged to purchase seed and lanterns so that time of maturity and hence cash return is staggered. Make no loans during the second turn but as companies decide how they wish to make their original investment, introduce them to the Oyster Stock Form. Be sure each company records the dates oyster stocks may be sold.

The bank pays 0.50% simple interest each month for bank balances. This is about 6% on an annual basis, and is approximately the same for a real bank. All money changes are made only on ledgers. Do *not* use play money. Using no certificates for money places more emphasis on record keeping.

The Third Turn

It is now March. Loans may be obtained and additional stock may be purchased. Loans may be negotiated by a throw of a single die. Odd numbers indicate a loan was rejected. A company may borrow an amount equal to $10,000 times a second throw of the die. In this and subsequent turns companies may purchase used equipment or oyster stocks from other growers at prices they negotiate. The bank simply oversees these transfers and charges the seller a 5% brokerage fee.

Other Rules

Loans

The principal of each loan must be paid on its anniversary month. Interest must be paid at the

rate of 1.5% each month. Payment is monthly and the bank must bill each company. Companies unable to pay can have assets seized by the bank, and sold at a negotiated price to other companies.

Sales

When oysters have reached marketable size, the price is determined by the throw of a single die.

Number on Die	Price
1	$0.50/oyster
2	$0.45/oyster
3	$0.40/oyster
4	$0.35/oyster
5	$0.30/oyster
6	$0.25/oyster

When a marketing sale is concluded, the bank acts in the role of purchaser.

Hardship

Starting with the fifth turn, each company must roll the die to determine if a hardship is encountered. Companies rolling odd numbers must draw a hardship card and abide by it.

Hardship Cards:

Damage to lanterns, lose 1/10 of the total number of modules. 3/4 of these are recoverable if the grower is willing to pay a flat fee of $300 to divers to retrieve them.

Troubles with the owner of the land, you lose your lease. You must now lease land next to your site, pay $4,000.

Ten lanterns damaged in a storm, must be replaced. No loss of seed.

Equipment damage due to a storm must double the labor cost for this month to correct problem, lose $2,000.

If you have a sale in this turn you will have to purchase 1/3 of the oysters which you would normally sell from another buyer at $0.40/oyster owing to the fact that your operation had problems getting all the animals in time to meet the order date.

You have experienced excessive fouling which resulted in the doubling of your labor costs for this month, lose $2,000.

You have experienced excessive sea squirt problems, double the cost of labor this month, lose $2,000. Applies only in summer.

If the calendar is September, October, April, May, the weather is cold, double the labor costs for this month, pay $2,000.

If you have any money in the bank which is collecting interest at 6%, you lose the interest from that money for this turn. If not, draw again.

There is an increase in interest rates, pay 2% per month on any loan negotiated this month.

Lantern manufacturer is late in delivery, lose 10% of stock needing larger quarters.

If it is December, January, February, you have lost 1/2 of your total oyster crop due to severe winter mortality. If it isn't one of these months, disregard card and do not draw again.

If it is November, December, January, February, you lose 1/3 of your total oyster crop due to severe storms. If not, disregard card but draw again.

Regardless of the month, lose 1/4 of the total number of oysters.

Regardless of the month, lose 1/10 of the total number of oysters.

Regardless of the month, lose 1/2 of the oysters 1 year old and younger and 1/10 of those oysters older than 1 year.

Regardless of the month, you have experienced a 90% mortality for all seed purchased this year and a 25% mortality for all other animals.

Raft destroyed in high winds — you must replace at a cost of $5000.

Raft damaged in storm repaired for $2,500.

50% of all the salable oysters this turn are infected with a disease and must be sold locally for $0.10 each.

The shipment sold last turn died in transit and the buyer refuses to pay you. Subtract this income from your budget.

Annual Fees and Payments

Leases and water rights licenses are renewed each January for $4,000 and $500 each. Federal and State taxes are calculated at the rate of 50% of all income from sales and bank interest. Taxes are due in April and *must* be paid. Players should be warned in August of the first "year" of play of this fact.

Determining the Winner

The game can continue indefinitely but should be run for at least fifty turns to allow the 3-5mm oysters to reach market size and for the grower to realize a profit from these animals. The game was designed to allow students to understand and appreciate some of the hardships involved in the aquaculture industry as well as providing experience in areas of mathematics and social studies. The game can be used as a jumping off point for discussions of some of the other activities listed in this unit especially a visit to or from an aquaculturist. If neither is possible students may prepare questions for a sea farmer or marine researcher to discuss as a taped interview.

Teacher Resources

Organizational Resources

These organizations can help by providing a variety of materials and services; we encourage you to contact them for assistance.

New England Aquarium
Central Wharf, off Atlantic Avenue
Boston, Massachusetts 02110
Telephone: (617) 742-8830

The Aquarium provides superlative classroom materials, in addition to being a favorite destination for annual field trips. The philosophy of the Aquarium is "to make known the world of water" through education, research, and recreation. The ARK (Aquarium Resource Kit) is available for two dollars. Although it is designed for classes that will visit, it has much valuable information on adaptation and coloration for any class. The Aquarium has a curriculum resource center which you may use by mail or in person.

New Hampshire Department of Resources and Economic Development
Judy Silverberg, Interpretive Specialist
Parks and Recreation Division
6 Louden Road
Concord, New Hampshire 03301
Telephone: (603) 271-3556

The Department offers a variety of educational services and resources. Write or call for details.

University of New Hampshire Marine Programs
Julia Steed Mawson, Marine Education Specialist
New England Center Administration Building
Durham, New Hampshire 03824
Telephone: (603) 862-1255

Many fine services for teachers are available trhough the UNH Marine Program including marine resource workshops for educators, programs at Odiorne State Park, and consultation with teachers to assist in their programs.

University of New Hampshire Marine Programs
Sharon Meeker, Docent Program Coordinator
New England Center Administration Building
Durham, New Hampshire 03824
Telephone: (603) 862-1255

Extensive special services include outreach programs in the schools, a speaker's bureau, and marine resource workshops.

Shoals Marine Lab
John Hieser, Director
Post Office Box 88
Portsmouth, New Hampshire 03801

The lab offers teachers workshops in marine science for educators.

State of Maine Department of Marine Resources
Lorraine Stubbs, Marine Science Educator
State House Station 21
Augusta, Maine 04333
Telephone: (207) 289-2291

The DMR has the ability to work with teachers and schools in setting up programs and planning curriculum. A speaker service with slide presentations can be tailored not only to your grade level, but your particular class interests and needs. Hands-on materials and answering questions are part of the presentation. Publications for use by teachers, which are free of charge, are abundant in the DMR library, as are many technical reports for teacher background material or intensive study projects by students. The department will also arrange for visits to aquaria or research labs. The highly-knowledgeable and skilled Lorraine Stubbs is responsible for these diverse and high-quality services.

University of Maine Sea Grant Marine Advisory Program
Sea Grant Office, Coburn Hall
University of Maine at Orono
Orono, Maine 04469
Telephone: (207) 581-2719

Sea Grant has many research and commercial aquaculture publications available, primarily of a technical nature. Marine researchers and local marine advisory service agents can be located through the Marine Advisory Program.

Northern New England Marine Education Project
Dr. John W. Butzow, Director
206 Shibles Hall
College of Education
University of Maine at Orono
Orono, Maine 04469
Telephone: (207) 581-7027

The primary purpose of this project is the production of marine education materials for use by teachers of Maine and New Hampshire. There are sixteen published multi-disciplinary units on a variety of topics for a range of grades, several of which could be adapted to your grade level. The unit you are now using is the first of five to be produced especially for middle/junior high school use. The project also sponsors workshops in schools, marine education conferences, and summer institutes.

The Nova Scotia Museum
Education Section
1747 Summer Street
Halifax, Nova Scotia
Canada B3H 3A6
Telephone: (902) 429-4610

The Museum offers you publications, resource kits, collections, and reponses to specific inquiries. For those living close to Halifax, a broader array of museum resources for school oceanography is available. Call or write for further information.

The International Atlantic Salmon Foundation
Box 429
St. Andrews, New Brunswick
Canada E0G 2X0

This organization participates in the maintenance of an experimental hatchery of Atlantic Salmon and funds salmon research and information activities on both sides of the border. They publish a newsletter and distribute a curriculum on Salmon called *Salar*. *Salar* includes student text, teacher guide and filmstrip.

The Huntsman Marine Laboratory
Brandy Cove
St. Andrews, New Brunswick
Canada E0G 2X0

The staff at HML operate a fine museum and aquarium in the summer and distribute information on a year-round basis.

Commercial Aquaculture Companies (Circa) 1981

Oysters and Mussels

John Smith
Pratt's Islands Road
West Southport, Maine 04569

Terry Haskell
Little Deer Isle
Box 533
Ellsworth, Maine 04654

Dodge Cove Marine Farm
Dick Clime & John Stewart
Box 211
Newcastle, Maine 04553

Maine Mooring Oyster Company
Chester Brown
South Bristol, Maine 04568

Spencer Fuller
Box 427
Vinalhaven, Maine 04863

Meritec
On the Gut
South Bristol, Maine 04568

Ken Gray
South Bristol, Maine 04568

Great Eastern Mussel Farms
Chip Davison/Frank Simmons
Damariscotta, Maine 04543

Spinney Creek Oyster Company
Ian Walker
Eliot, Maine 03930

Marine Bioservices
John Sheldon
High Island
South Bristol, Maine 04568

Deborah Cameron
134 Dummer Street
Bath, Maine 04530
(207) 443-5956

Abandoned Farms, Inc.
Edward Myers
Damariscotta, Maine 04543

Richard Foxwell
Box 40
Lincolnville, Maine 04849

Boothbay Aquaculture
James Greenleaf and Lester Rhoads
Boothbay, Maine 04537

Finfish

Bill and Nancy Blake
Quarry Enterprises
St. George, Maine 04860

Duck Trap River Company
Des Fitzgerald
RFD 1
Lincolnville, Maine 04849

Evelyn Sawyer
Sea Run, Inc.
RFD 2
Kennebunkport, Maine 04046
(207) 985-7957

Equipment

Sheepscot Oyster Company
Reg & Gil Gillmore
Box 286
Newcastle, Maine 04553

Professional Help

State of Maine Department of
Marine Resources Laboratory
McKown Point
Boothbay Harbor, Maine 04530

Laboratory Supply Houses

Berkshire Biological Suppy Company
P.O. Box 404
Florence, Massachusetts 01060
Telephone: (413) 586-6149

Connecticut Valley Biological Supply Company Inc.
Valley Road, P.O. Box 326
South Hampton, Massachusetts 01073

Carolina Biological Supply Company
Burlington, North Carolina
Toll Free Telephone: (800) 334-5551

CENCO
160 Washington Street
Somerville, Massachusetts 02143
Telephone: (617) 776-1800

Turtox/Cambosco
MacMillan Science Company, Inc.
8200 South Hoyne Avenue
Chicago, Illinois 60620
Toll Free Telephone: (800) 621-8980

Wards Natural Scientific Establishment, Inc.
P.O. Box 1712
Rochester, New York 14603

Technical Bibliography

This bibliography is included for the teacher or advanced student who wants technical detail. Many of the publications are rare or out of print. Sea Grant Advisory Services and University or State Libraries may be the only sources of some of these.

Bardach, John E., John H. Ryther, and William O. McLarney. 1972. ***Aquaculture: the Farming and Husbandry of Freshwater and Marine Organisms.*** Wiley Interscience, New York.

Bayne, B.L. 1965. Growth and the delay of metamorphosis of the larvae of *Mytilus edulis*. ***Ophelia 2***(1):1-47.

Brooks, William. ***The Oyster.*** Baltimore: The John Hopkins Press, 1905.

Cowger, Joel. Natural Occurence of the American Oyster, *Crassostrea virginica*, in Maine and its Relevance to the Critical Areas Program. State Planning Office, Report #4, 1975.

Dow, R.L. ***Marine and Estuarine Culture in Maine.*** Fisheries Circular No. 24, Maine Department of Marine Resources, Augusta, Maine, 1970.

Dow, R.L. ***Partial Report of Aquacultural Studies Conducted by DMR.*** 1969-1973. DMR. Augusta.

Dow, R.L. and D.E. Wallace. 1954. ***Blue Mussels (Mytilus edulis) in Maine.*** Department of Sea and Shore Fisheries Bulletin.

Ehrbar, Charleen. ***The New Maine Oyster Industry.*** Maine Sea Grant Information Leaflet 11. September 1975.

Field, I.A. 1922. Biology and economic value of the sea mussel *Mytilus edulis*. ***Bull. U.S. Bur. Fish. 38***:127-259.

Foster, Walter. ***Cobscook Bay Aquacultural Potential.*** Maine Department of Marine Resources. Bull. #36, State House, Augusta, Maine 04330, March 1976.

Foster, Walter. ***Ecological Considerations in Oyster Bottom Culture.*** Research Bulletin No. 37, State of Maine Department of Marine Resources, June 1976.

Galtsoff, P.S. The American Oyster. ***U.S. Fish and Wildlife Serv. Fish. Bull.***, 1927, 64:480 pp.

Gates, J.M., G.C. Matthiessen, C.A. Griscom. 19. ***Aquaculture in New England.*** Univ. of Rhode Island, Sea Grant Office, Report #18.

Hidu, Herbert, and Mark Richmond. 1974. ***Commercial Oyster Aquaculture in Maine.*** University of Maine Sea Grant Program, Sea Grant Bulletin #2.

Jensen, Kathi, (ed.) ***Aquaculture 1976: A Digest of Sea Grant Research.*** Sea Grant Office, University of D.E., Newark, D.E. 1971.

Lutz, Mark. ***Mussel Culture and Harvest.*** New York: Elsvner Pub. Co., 1980.

Lutz,R.A. 1974. ***Raft Cultivation of Mussels in Maine Waters — Its Practicability, Feasibility, and Possible Advantages.*** Maine Sea Grant Bulletin 4, Darling Center, Walpole, Maine.

Lutz, R.A. and L.S. Incze. 1977. ***A Comprehensive Review of the Mussel Industry in the United States.*** National Marine Fisheries Service, Department of Commerce (March, 1977).

McKee, A. ***Farming the Sea.*** New York: Thomas Crowell Co., 1969.

McNeil, W.J., ed. ***Marine Aquaculture.*** Corvallis, Oregon: Oregon State University, 1970.

Pratt, Robert S. 1976. ***Potential of Aquaculture Under H.J. 1833. Public Hearings on Aquaculture***, U.S. Government Printing Office, Washington, D.C.

Pratt, Robert S. 1976. ***Prospects for Shellfish Culture Utilizing H.R. 1833,*** Ira C. Darling Center, Walpole, Maine.

Richmond, Mark S. ***Oyster Culture in Maine, Specifications and Approximate Costs of Rearing Equipment.*** Maine Sea Grant Leaflet 5. August 1974.

Ryther, J.H. 1968. ***The status and potential of aquaculture particularly invertebrate and algae culture. Vol. I, Part II. Invertebrate and algae culture.*** Washington, D.C., American Institute of Biological Sciences.

Scattergood, L.W. and C.C. Taylor. 1949. The mussel resources of the North Atlantic Region. Part I. The survey to discover the location and areas of the North Atlantic mussel-producing beds. ***Comm. Fish. Rev. 11***(10:1-10.

Schwind, P. ***Practical Shellfish Farming.*** Camden, Maine: International Marine Publishing Company, 1977.

Shaw, W.N. Raft Culture of Eastern Oysters in Chatham, Massachusetts. ***Proc. Nat. Shellfish Assoc.,*** 1960, 51:81-93.

Shaw, W.N. The Growth and Mortality of Seed Oysters, *Crassostrea virginica*, from Broad Creek, Chesapeake Bay, Maryland, in High and Low Salinity Waters. ***Proc. Nat. Shellfish Assoc.,*** 1966, 56:67-72.

Stillings, B.R. 1969. New Foods from the Sea. In: Caster, W.O., ed. 1969. ***The Promises and Problems of the New Foods.*** Report #3 Inter-Institutional Committee on Nutrition, University of Georgia, Athens, Georgia.

Welch, W.R. The European Oyster *Ostrea edulis* in Maine. ***Proc. Nat. Shellfish Assoc.,*** 1963, 54:7-24.

Annotated Bibliography

The following bibliography should be of help to students and teachers to further their knowledge of this vast subject.

Amos, William H. ***The Life of the Seashore.*** New York: McGraw-Hill Book Company, 1966.

From "Our Living World of Nature" series, published in cooperation with The World Book Encyclopedia, this volume is beautifully illustrated, well-organized, and has a good writing style. Uses an ecological approach with specific examples.

Bardach, John. ***Harvest of the Sea.*** New York: Harper and Row Publishers, 1968.

This book evaluates present, probable, and possible developments regarding the ocean environments. Examines the means by which people can best utilize the potential of the sea. General reading.

Clark, Eleanor. ***The Oysters of Locmariaquer.*** New York: Pantheon Books, 1964.

Substantially worthwhile reading for anyone interested in the pleasures and hardships of a fisherman. This novel is set in Brittany on the northwestern shore of France and describes many lifeline situations involved in harvesting the oceans' resources.

Cousteau, Jacques. ***The Ocean World of Jacques Cousteau: The Sea in Danger.*** New York: World Publishing, 1974.

Cousteau's style shines through on this informative publication. It gives many accounts of where mankind stands in relation to the oceans. Lavishly illustrated with color photography, it presents many perplexing questions for the human race.

Department of Marine Resources. ***Marine Resources Laws and Regulations.*** Augusta, Maine, 1981.

A recent shell fishing lawbook can be obtained from the State of Maine Department of Marine Resources which discusses the various laws concerning the gathering and raising of shellfish commercially and for personal use. ***Maine Marine Resources Laws and Regulations*** is revised periodically. Address Lawbook request to: Department of Marine Resources, State House Station 21, Augusta, Maine 04333.

Hanson, Joe A., ed. ***Open Sea Mariculture.*** Stroudsburg, Pennsylvania: Dowden, Hutchinson, and Ross, Inc., 1974.

This work is a compendium of research on perspectives, problems, and prospects of open sea mariculture undertaken by the National Oceanic and Atmospheric Administration and the Oceanic Foundation. It is comprehensive in scope and was written by experts in each field.

Idyll, C.P. ***The Sea Against Hunger.*** New York: Thomas Y. Crowell Company, 1978.

This is perhaps the best book on this subject in the Project's experience. Presents a critical examination of humankind's chance of avoiding widespread hunger by increasing the use of food from the sea. The book's many revelations will create an understanding of the ocean's resources and natural processes and how we should act if the sea is to increase its share of nutrition for humanity. It also contains good bibliography

Stubbs, Lorraine. ***The American Lobster.*** Fisheries Education Unit #13, Department of Marine Resources, Augusta, Maine, 1979.

Thorson, Gunnar. ***Life in the Sea.*** New York: McGraw-Hill Book Company, 1973.

From the "World University Library" series, this superb volume is packed full of worthwhile information and could easily be considered a standard in this area of study. It is very well-organized, accurately written, and excellently illustrated. Written for the novice as well as the expert.

Zim, Herbert S., and Krantz, Lucretia. ***Commercial Fishing.*** New York: William Morrow and Company, 1973.

This is a first rate book for middle grade students. It presents many important facets of the commercial fishing industry throughout the world, while also giving a good account of how all people can and do benefit from the sea's resources.

Zinn, Donald J. ***Handbook for Beach Strollers from Maine to Cape Hatteras.*** Chester, Connecticut: The Pequot Press, 1975.

This charming little book covers marine life from reproduction and life cycle to good recipes. It is simply written and appeals to a wide age range.

A Bibliography of Cook Books

This bibliography contains books about seafood and different ways of preparing it. For those who are fed up with fast-food restaurant chains and expensive dining out, there are many alternatives, as you will find in these books. Also presented are many regional and ethnic seafood specialties, as well as bizarre and exotic recipes, breads, and about everything imaginable that goes with seafood.

Since one of the main concerns of modern living is a healthy and nutritious diet, people should eat more seafood. It is low in calories and high in protein. Many species provide vitamins and minerals of unexcelled quality. It is often simple to prepare, requiring few cooking materials and is indescribably delicious. Whether chef, homemaker, or occasional cook, you are sure to find something of interest included in some of these volumes.

Alberson, Sarah D. ***The Blue Sea Cookbook.*** New York: Hastings House, 1968

Brody, Jerome. ***The Grand Central Oyster Bar and Restaurant Seafood Cookbook.*** New York: Crown Publishers, Inc., 1977.

Day, Bunny. ***Catch'em and Cook'em.*** Garden City, New York: Doubleday and Company, Inc., 1961.

Hill, Paul J. and Mavis A. ***The Edible Sea.*** New York: A.S. Barnes and Company, 1975.

Miloradovich, Milo. ***The Art of Fish Cookery.*** Garden City, New York: Doubleday and Company, Inc., 1970.

Ross, Shirley. ***The Seafood Book.*** New York: McGraw-Hill Book Company, 1978.

Spear, Ruth A. ***Cooking Fish and Shellfish.*** Garden City, New York: Doubleday and Company, Inc., 1974.

Zachary, Hugh. ***The Beachcomber's Handbook of Seafood Cookery.*** Winston-Salem, North Carolina: John F. Blair, Publisher, 1969.

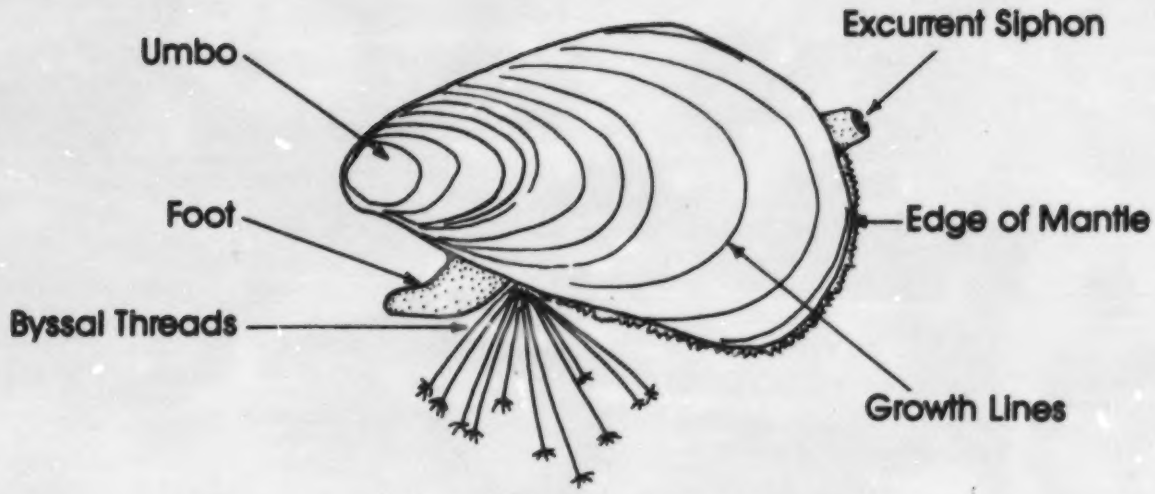


Figure 1. Mussel Exterior

Figure 2. Mussel with attached drill.

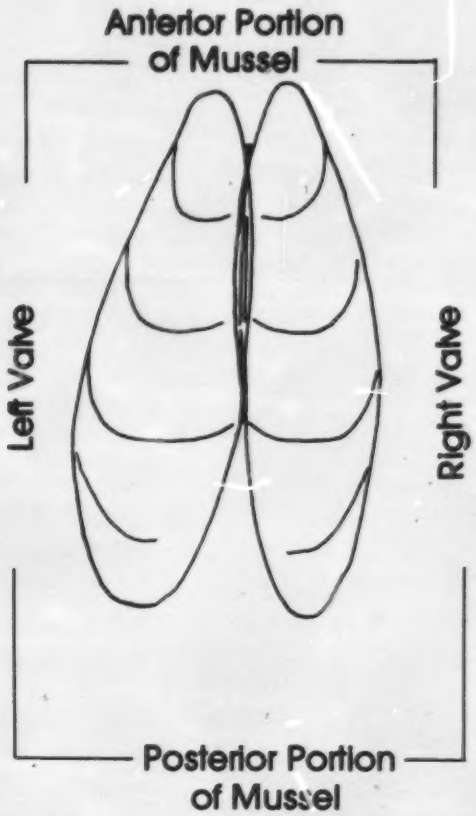


Figure 3. Mussel showing left/right valve orientation.

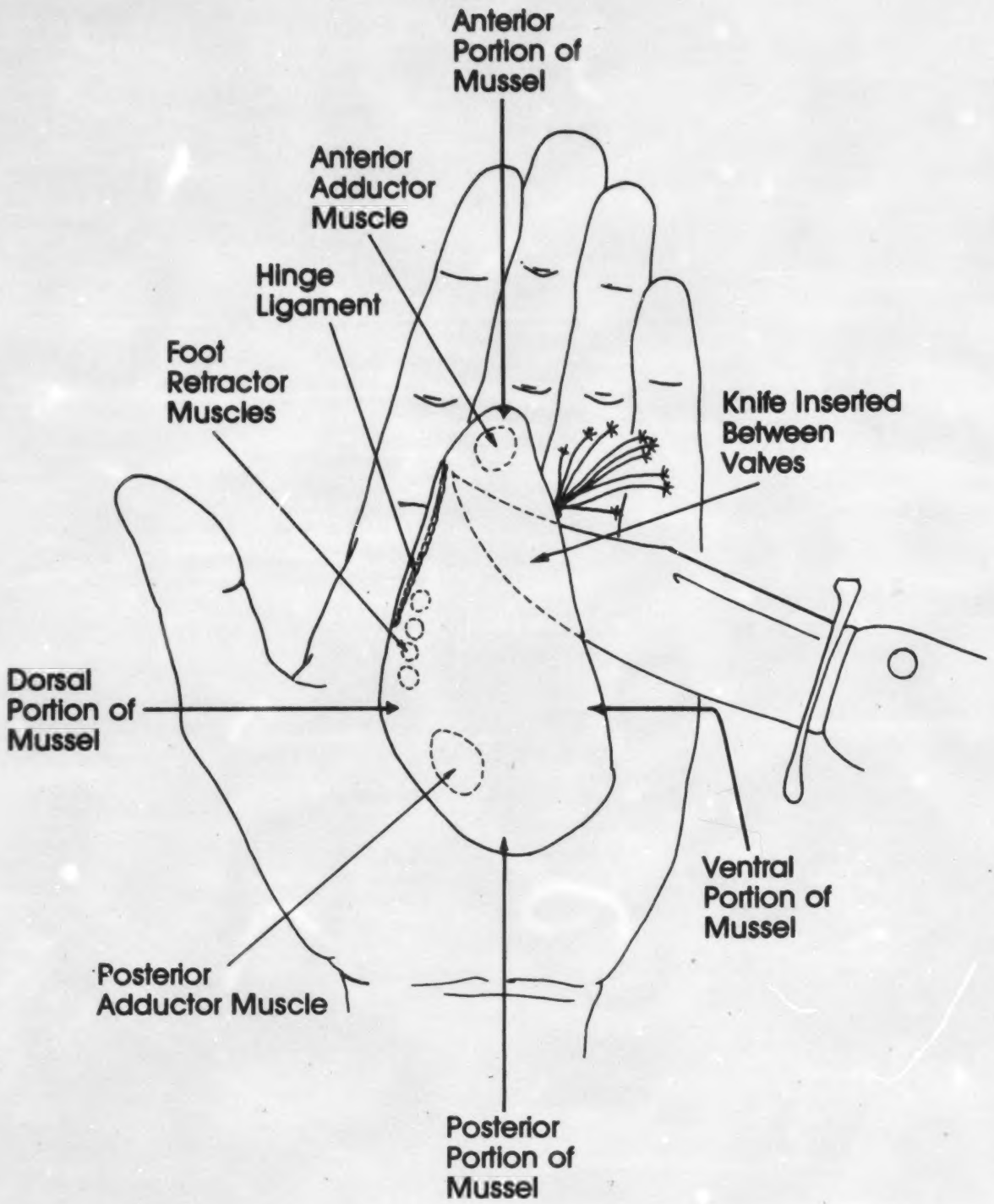


Figure 4. Mussel oriented in hand for beginning dissection.

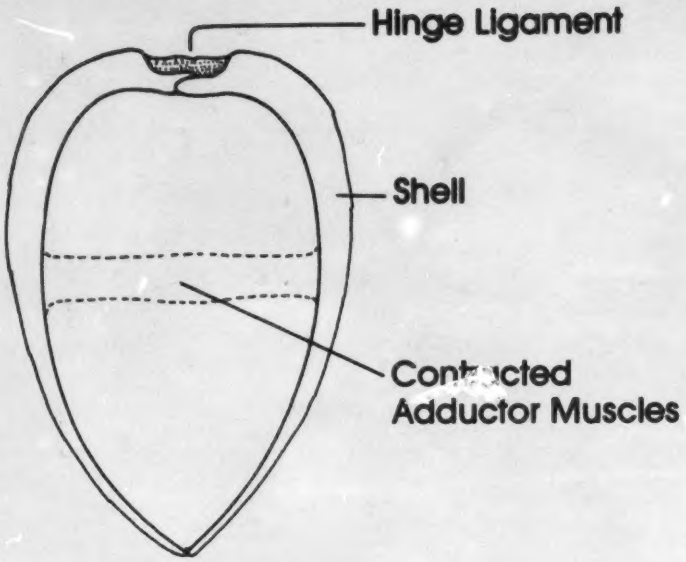


Figure 5. Closed valves.

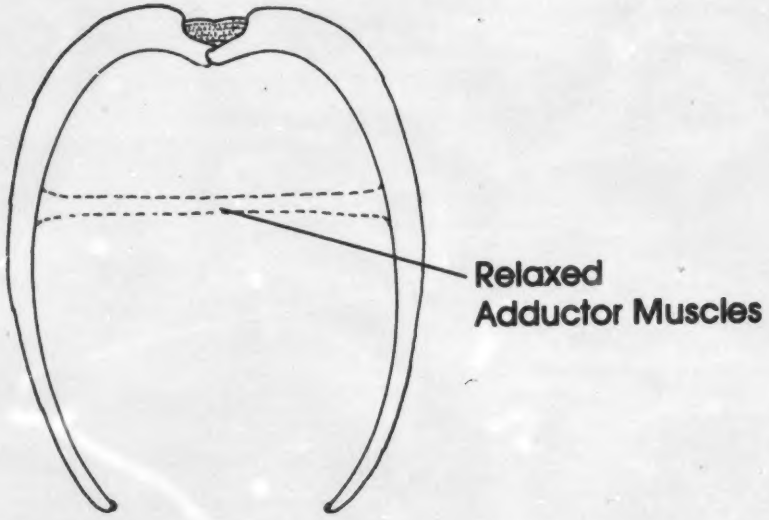


Figure 6. Open valves.

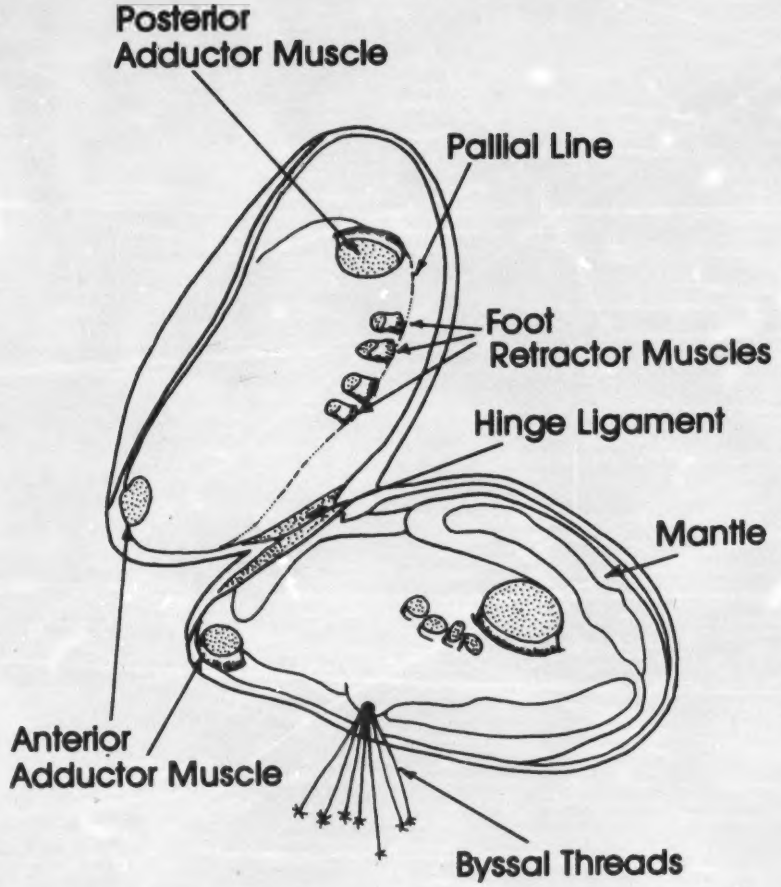


Figure 7. Mussel with left valve lifted.

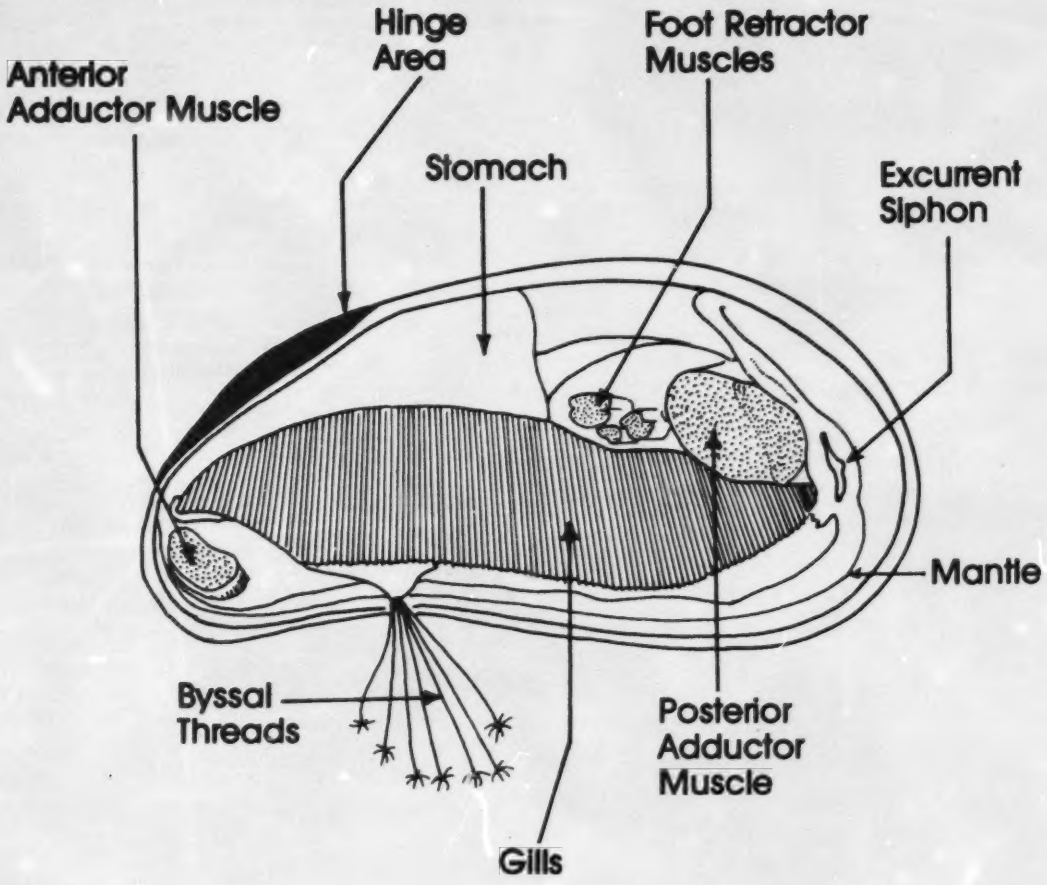


Figure 8. Mussel with left valve removed, exposing gills.

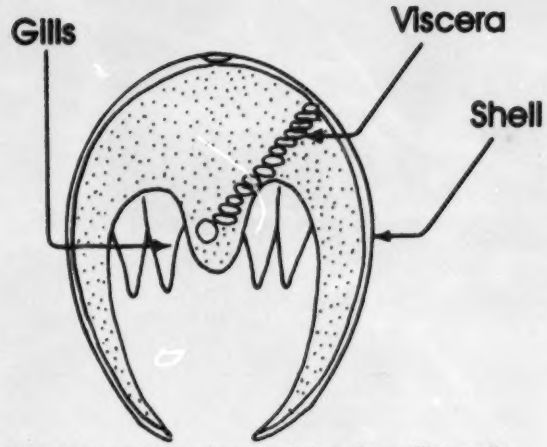


Figure 9. Cross-section of mussel showing gill location.

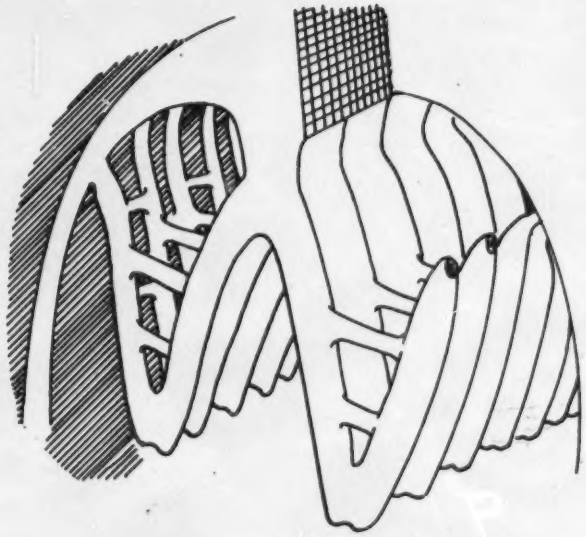


Figure 10. Gill detail.

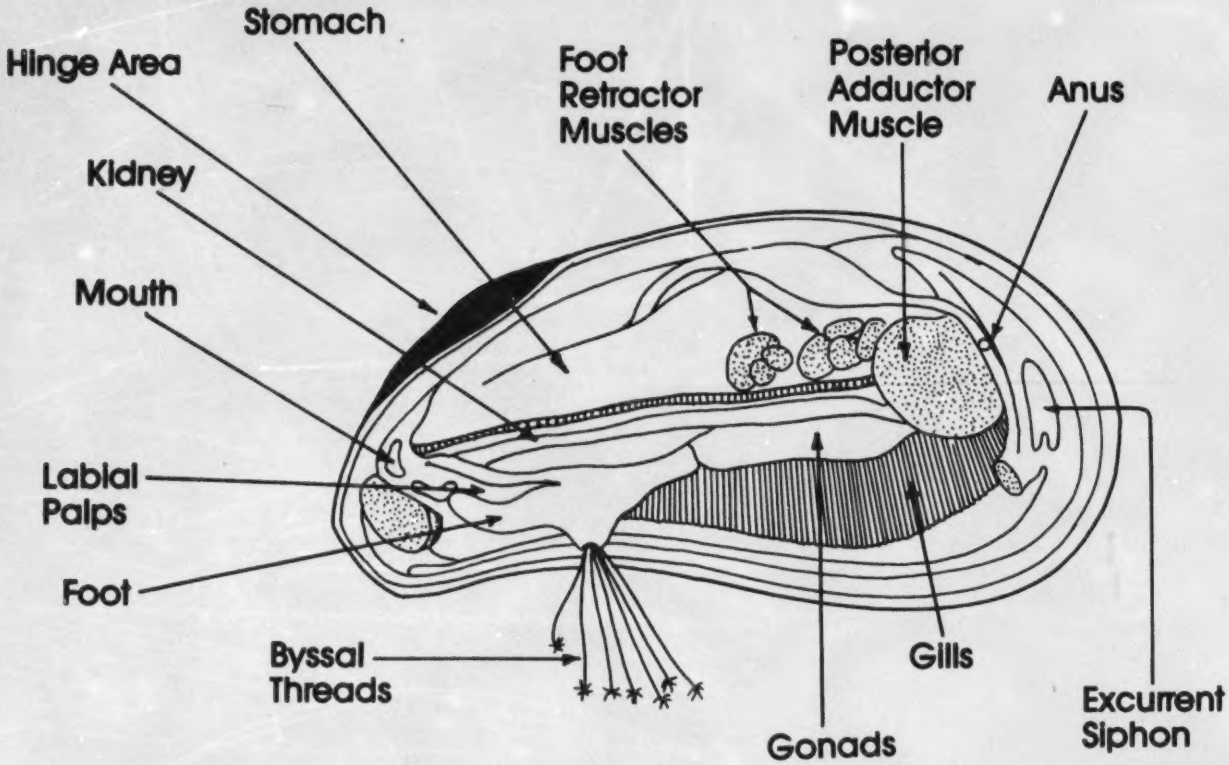


Figure 11. Mussel with left valve and gill removed to expose organs.

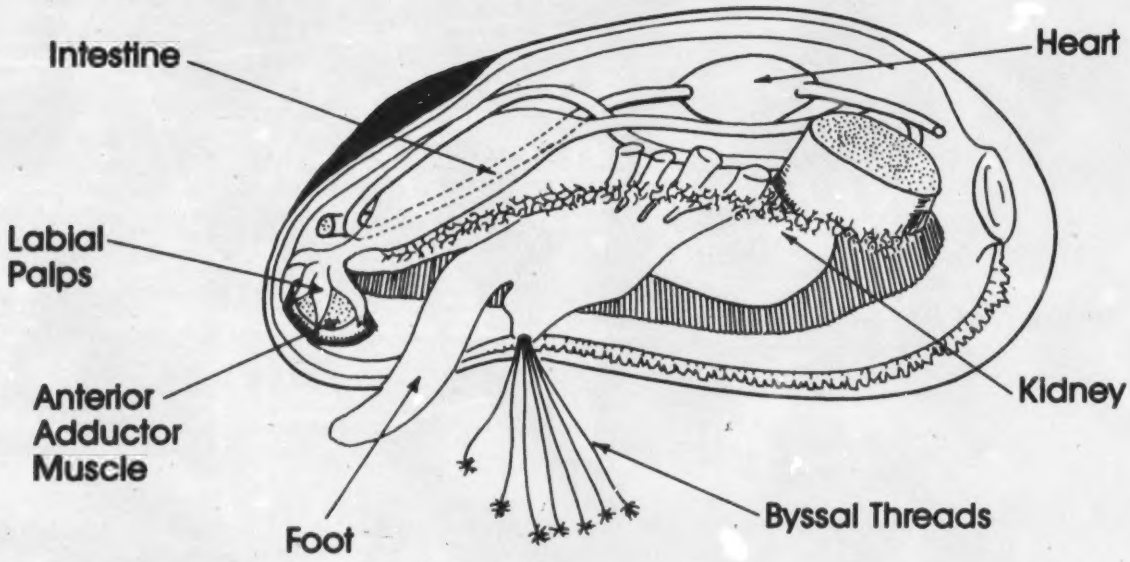


Figure 12. Anatomical drawing showing intestinal tract.

OYSTER STOCK FORM for the year _____

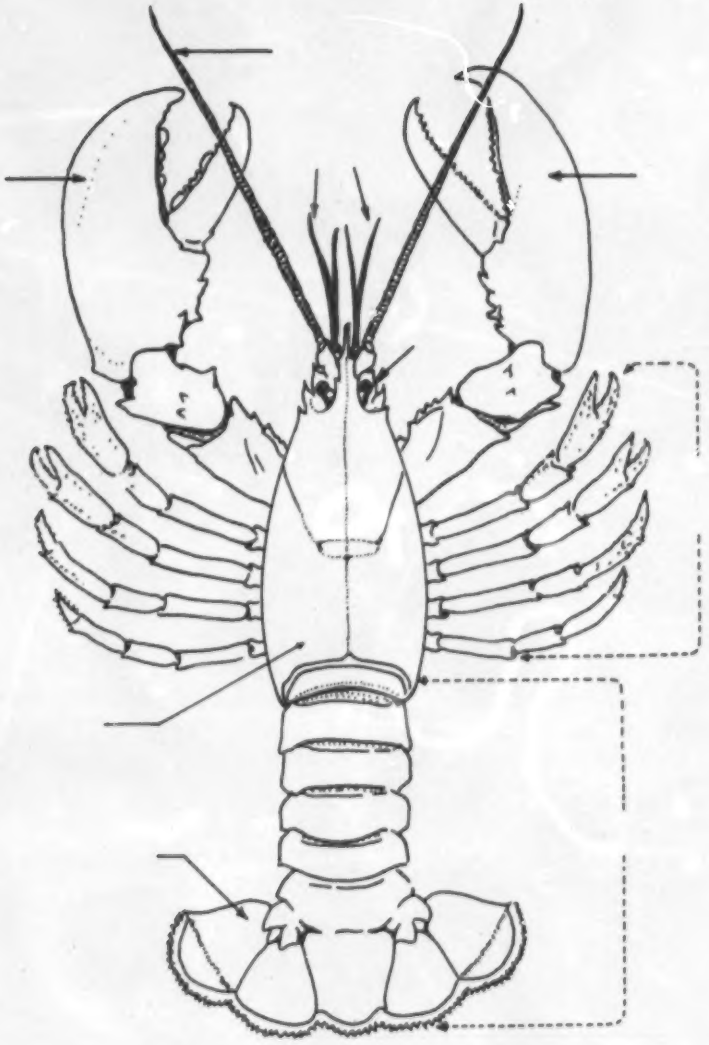
Company Name _____

Month	Size	Number	Cost	Date Salable	Total Costs	Available Funds	Adjusted Budget (avail. for next month)

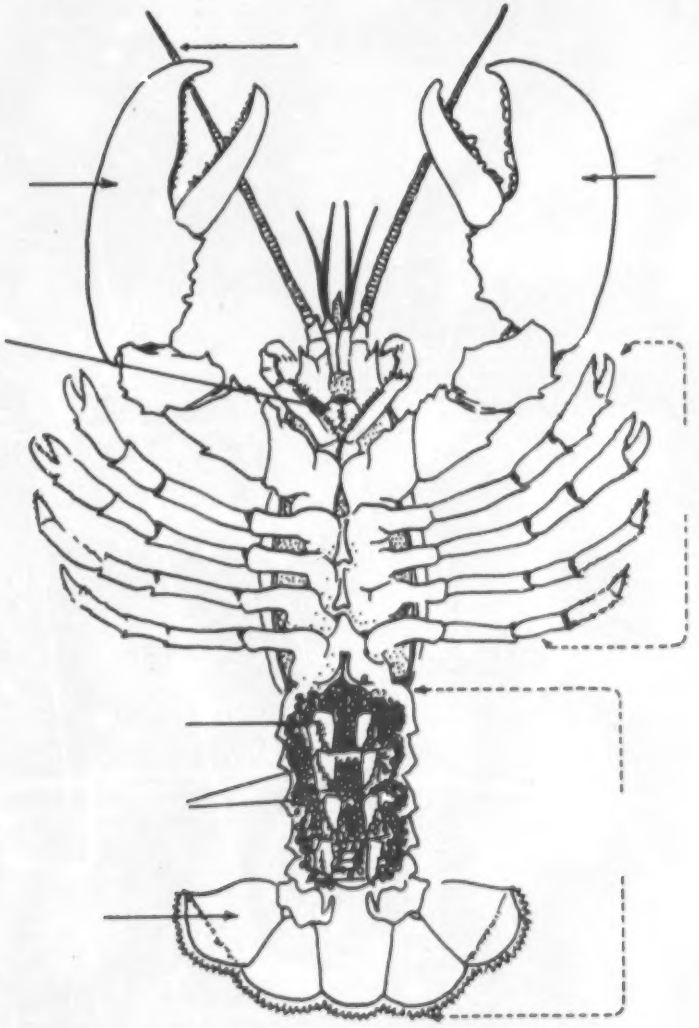
BANK BALANCE FORM

Company Name _____

Month	Capital Investment	Amount Borrowed	Interest 1.5%/mo.	Total Owed Interest & Principal	Payments	Adjusted Total Owed



52



53